STATE-COUPLED LOW TEMPERATURE GEOTHERMAL
RESOURCE ASSESSMENT PROGRAM,
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FINAL TECHNICAL REPORT

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FOREWORD

This report summarizes the results of low-temperature geothermal energy resource assessment efforts in New Mexico during the period from 1 October 1978 to 30 June 1980 under the sponsorship of the U.S. Department of Energy (Contract EW-78-S-07-1717) and the State of New Mexico Energy and Minerals Department (Grants 77-2211 and 78-2218). The research program was administered by the New Mexico Energy Institute at New Mexico State University and the research was conducted by university faculty members at New Mexico State University, the University of New Mexico, and the New Mexico Institute of Mining and Technology.

The report is divided into two major sections. The results of the efforts to extend the inventory of geothermal energy resources in New Mexico to low-temperature geothermal reservoirs with the potential for direct heating applications are given in Section I. These efforts focused on compiling basic geothermal data, which were acquired through previously funded research programs, and on new hydrology and temperature gradient data throughout New Mexico in a format suitable for direct transfer to the U.S. Geological Survey and the National Oceanic and Atmospheric Administration for inclusion in the GEOTHERM data file and for preparation of New Mexico low-temperature geothermal resources maps. Funding from the United States Geological Survey, the National Science Foundation and the State of New Mexico Energy and Minerals Department supported work from which some data compiled in this research effort were taken. The Department of Energy support permitted the extension of some data sets in addition to the compilation of all data into a common format. Section II contains the results of geothermal reservoir confirmation studies, funded concurrently by the Department of Energy and the State of New Mexico Energy and Minerals Department.

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SECTION I

STATEWIDE GEOTHERMAL EVALUATION OF

NEW MEXICO

Chapter 1

Subsurface Temperatures of Geothermal Resources

Part 1

Estimated Subsurface Temperatures*

Ranking Criteria

On the basis of the silica and NaKCa geothermometers, "best guess" subsurface temperature estimates have been prepared and listed in Tables 1, 2 and 3 in order of descending geothermal potential. The criteria used in the subsurface temperature estimates are the same as employed by the U.S. Geological Survey in the preparation of Circular 726 (White and Williams 1975). If the two geochemical temperatures are in good agreement, an approximate average is used. If there is a large discrepancy in the two geochemical temperatures, the lower value is taken. In some cases, mixing models have been employed. These cases are designated by a check mark in Table 1.

Several hot spring areas, including two KGRAs and Turkey Creek Hot Spring, do not yield chemical temperatures in excess of adjacent non-thermal waters. These areas are given a subsurface temperature estimate of LT (low temperature) and are listed in Table 3 in order of descending surface temperature. Figures 1 through 3 show the area distribution of the data used in constructing Tables 1, 2 and 3. Since the Basin and Range Province extends into west Texas, Figures 1 through 3 include west Texas data for completeness.

*The principal author of Chapter 1, Part 1 is Dr. Chandler A. Swanberg, Associate Professor of Physics and Earth Sciences, New Mexico State University.

Table 1. Major geothermal areas of New Mexico sampled and their subsurface temperatures (°C) calculated by using the silica and NaKCa geothermometers.

Name	Lat.	Long.	T _{Surface}	T _{SiO₂}	T _{NaKCa}	T _{Subsurface}
Valles Caldera*	35 43	106 32	87	177	234	240
Lightning Dock*	32 08.5	108 50	99	160	167	170
Guadalupe Area	35 30	107 15	35	156	177	170
Hillsboro Area	31 57.2	107 34.8	34	162	169	165
Columbus Area	31 45	107 30	31	135	195	✓ 155
Kilbourne Hole*	31 45	106 50	28	133	200	✓ 155
Lower Frisco*	33 15	108 47	49	132	148	150
Radium H. S.*	32 30	106 55.5	53	118	223	✓ 130
Ojo Caliente	36 18.3	106 03.0	56	122	161	130
Montezuma H. S.	35 39.2	105 17.4	59	122	140	130
Mamby's H. S.	36 31.6	105 40.6	41	116	168	✓ 125
San Diego Mountain	32 38	106 58	52	105	233	✓ 125
Mesquite-Berino	32 10.0	106 40.0	31	112	175	✓ 120
Las Alturas	32 15.0	106 46.0	63	109	179	✓ 120
Ponce de Leon	36 19.4	105 36.5	34	106	92	105
Truth or Consequences	33 08.1	107 15.2	45	96	180	✓ 100
San Ysidro	35 35	106 50	52	89	160	100
Derry Spring	32 47.6	107 16.6	33	83	156	✓ 100

*KGRA

✓ Estimated subsurface temperature in the 150 to 200°C range of mixing models are applied to the silica data.

Table 2. Additional major geothermal areas from WATSTORE and their subsurface temperatures (°C).

Name	Lat.	Long.	T _{Surface}	T _{SiO₂}	T _{NaKCa}	T _{Subsurface}
Southern Tularosa Basin	32 05	106 05	71	---	---	~150
White Sands (Town)	32 25	106 25	54	114	160	~150
North of Socorro	34 20	106 50	41	110	166	~150
Prewitt Area	35 260	107 53.0	46	~100	~200	~150
Jemez Reservoir	35 20	106 40	warm	~120	~150	~150
Lordsburg	32 13.7	108 30.7	33	91	151	~150

Table 3. Major low temperature geothermal areas in New Mexico and their subsurface temperatures (°C).

Name	Lat.	Long.	T _{Surface}	T _{SiO₂}	T _{NaKCa}	T _{Subsurface}
Turkey Creek H. S.	33 06.5	108 29.0	74	117	68	L. T.
Gila Hot Springs*	33 10	108 10	66	129	77	L. T.
Closson	35 15.5	108 19.4	61	95	51	L. T.
Fort Wingate	35 30	108 35	61	--	--	L. T.
Mimbres H. S.	32 44.9	107 50.1	58	107	75	L. T.
Faywood H. S.	32 33.3	107 59.7	54	97	78	L. T.
Tohatchi	35 55.3	108 34.7	39	66	82	L. T.
San Francisco H. S.	33 49.8	108 47.9	37	97	52	L. T.
Crown Point	35 41.6	108 08.4	37	60	80	L. T.
E. San Augustin Plain	34 00.5	108 05.5	35	108	53	L. T.
Socorro*	34 05.0	106 57.0	34	61	72	L. T.
Garton Well	32 46.8	106 09.0	34	63	100	L. T.
Cliff Area	32 52.6	108 35.0	31	85	53	L. T.

*KGRA

Figure 1. Subsurface temperatures in New Mexico and west Texas calculated by using the silica geothermometer.

Figure 2. Subsurface temperatures in New Mexico and west Texas calculated by using the NaKCa geothermometer.

Figure 3. In-situ temperatures of wells and springs in New Mexico and west Texas.

Geothermal Areas

The major geothermal areas in New Mexico are listed in Table 1 and shown in Figure 4. It is clear from Figure 4 that the majority of promising geothermal prospects in New Mexico are located within the Rio Grande Rift, a tectonic province running north-south through the center of the state and containing the state's major population centers. Several prospects are located near the boundary of the Colorado Plateau, a boundary that is also associated with geothermal resources in Utah, Arizona, and Colorado. A lesser number of promising prospects are located in the Basin and Range Province and the Colorado Plateau. There is no convincing evidence of any geothermal activity east of the Rio Grande Rift. Nearly all geothermal prospects in New Mexico are located within the high heat flow zone (100 mWm^{-2} ; 2.5 HFU) delineated by Reiter et al. (1975).

Although the data listed in Tables 1, 2 and 3 and Figure 4 are self-explanatory, a few areas are worthy of special mention.

Valles Caldera

There appear to be three different types of thermal water in the Valles Caldera area. Sulphur Springs is an acid sulphate type water containing very little chloride and appears to represent effluent from a vapor-dominated portion of a major geothermal system. Several other springs, such as Jemez Springs, yield geochemical temperatures in excess of 200°C and probably represent effluent from the liquid-dominated portion of the same geothermal system. A similar co-existence of liquid- and vapor-dominated portions of a geothermal system has been observed by White et al. (1971) in Yellowstone Park. A third type of thermal water, such as Spence Spring, consists of high quality waters yielding geochemical

temperatures which are not above regional background. These waters are not part of the major geothermal system. For a further treatment of this area, the reader is referred to Trainer (1975).

Southern Rio Grande Rift

There is so much geothermal water in the southern Rio Grande Rift that it is difficult to delineate specific sites at the scale of Figure 4. A more detailed description of this area is given by Swanberg (1975). Most of the thermal wells and springs give silica and NaKCa temperatures of about 115°C and 200°C, respectively. However, if mixing models are applied, both geothermometers give temperatures near 200°C. The hottest of these appear to be in the Radium Springs-San Diego Mountain area. Mixing models could not be applied to the Kilbourne Hole-Columbus area because the wells have nearly the same temperature. The hot wells in the White Sands-Southern Tularosa Basin area could not be studied because of limited access to the military land.

Socorro Area

The warm springs in the Socorro area do not show geothermal potential on the basis of their chemical constituents and are ranked far down the list of prospective geothermal prospects (see Table 3). However, several wells to the north of the KGRA which were included in the WATSTORE file appear to be of thermal origin. This area is included in Table 2.

Carlsbad Area

Although there are no warm wells or springs in the Carlsbad area, several of the groundwaters yield very high geochemical temperatures. It

is most likely that the NaKCa data are too high due to the presence of potash deposits and the silica data are too high because of the presence of amorphous silica in several of the aquifers. However, this area is located on a major lineament and is included in Figure 4 for completeness.

Gila Area

The Gila Hot Springs KGRA is given a subsurface temperature estimate of 125°C by the USGS (White and Williams 1975). This estimate is supported by the silica geotemperatures but is not supported by the NaKCa geotemperatures which generally fall in the 70 to 80°C range (Table 3). However, Gila is an area of silicic volcanics and the non-thermal waters (and in some cases the surface waters) also give silica geotemperatures as high as 110°C. Thus, there is no convincing evidence of high subsurface temperatures from the chemistry, so the Gila Hot Springs KGRA is listed in Table 3 with the other low temperature geothermal resources.

Hillsboro Area

The Hillsboro area is represented by a single warm spring, which is actively depositing sinter and shows very high geothermal potential (Swanberg 1980a). This spring is not referenced in the standard geothermal literature.

Additional Low Temperature Resource Areas (20 to 30°C)

The U.S. Department of Energy has established 20°C as the cutoff temperature for designation as a geothermal water and such low temperature waters may have applications in agriculture, heat pump applications and other uses. For the state of New Mexico, roughly half of all wells exceed

20°C, thus making the entire southern portion of the state a proven geothermal resource area. In the present manuscript, only hot springs and wells in excess of 30°C are shown individually (e.g., see Figure 3). Groundwaters in the 20 to 30°C range are shown separately in Figure 5. The southwest-northeast contour shown in Figure 5 denotes the approximate location of groundwaters exceeding 20°C. That is, any well drilled to the water table south of the contour will probably exceed 20°C with the obvious exception of the high mountain areas such as the Sacramento Mountains. North of the contour, wells drilled to the water table will generally be colder than 20°C. Also shown in Figure 5 are four geographic divisions of New Mexico. Figures 6 and 7 show the temperature of waters in these geographic divisions. The temperature data in Figures 6 and 7 form the basis for drawing the contour shown in Figure 5. For the Basin and Range and the Southeast Plains, 67 percent and 79 percent of all groundwaters exceed 20°C, respectively. However, for the Colorado Plateau and the Northeast Plains, only 32.2 percent and 28 percent of the groundwaters exceed 20°C, respectively.

Conclusions

Geochemical data from Swanberg (1980) has been used to estimate subsurface temperatures for geothermal areas in New Mexico. These data consist of major, minor, and trace elements for thermal wells and springs in New Mexico in addition to several thousand non-thermal groundwaters. Quantitative and qualitative geothermometers have been applied to these data in order to establish the location and potential of the state's geothermal resources. On the basis of the geochemical data, the state's geothermal resources have been ranked in the order of descending subsurface temperature estimates. Maps have been prepared showing the location of

Figure 5. Locations in New Mexico where any well drilled into the water table should exceed 20°C.

geothermal prospects. On the basis of the geochemical data, the following conclusions seem to be justified.

1. At least 7 and possibly as many as 20 discrete areas may have subsurface temperatures in excess of 150°C; that is, sufficiently high temperatures for potential economic development of electricity (see Table 1).
2. The majority of the high temperature geothermal prospects are located within the Rio Grande Rift, a tectonic province which includes the state's major population centers.
3. Several geothermal prospects such as the Southern Tularosa Basin are associated with large volumes of geothermal brine and are ideally suited for geothermal desalination.
4. Numerous geothermal prospects in western New Mexico consist of high quality, high temperature water, but apparently do not have sufficient subsurface temperatures for electricity generation. These prospects appear ideal for direct heat utilization such as space heating and agricultural applications.
5. Nearly all groundwaters in southern New Mexico have temperatures in excess of 20°C, the minimum temperature designated by the U.S. Department of Energy for low temperature utilization. Industries requiring (or having the ability to utilize) such waters should find a nearly inexhaustible geothermal resource in southern New Mexico.

Figure 6. Histogram of groundwater temperatures in the Basin and Range and the Southeast Plains.

Figure 7. Histogram of groundwater temperatures in the Colorado Plateau and the Northeast Plains.

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Part 2

Catalogue of Thermal Waters*

Sources of Data

One of the basic objectives of the present study is to compile a catalogue of thermal wells and springs in New Mexico. These wells and springs would then constitute a basic data base for both the Department of Energy (DOE)/National Oceanic and Atmospheric Administration (NOAA)/New Mexico Energy Institute (NMEI) public and scientific geothermal maps. The data will also be submitted to the U.S. Geological Survey (USGS) for inclusion into the geothermal file GEOTHERM.

In compiling the catalogue of thermal wells, two major (and independent) geothermal assessment studies of New Mexico's geothermal areas (References 1 and 2) were used extensively. These studies were then supplemented by additional information from the published literature, from unpublished results of various researchers working in New Mexico, and, where possible, from the files of private industry. The basic sources of information are as follows:

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*The principal author of Chapter 1, Part 2 is Dr. Chandler A. Swanberg, Associate Professor of Physics and Earth Sciences, New Mexico State University.

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Editing

Once this vast amount of geothermal data was compiled, it had to be edited and evaluated. This was accomplished in the following stages:

1. By using so many diverse sources of data, some overlap (i.e., different sources reporting the same information) resulted. The duplicate records were removed from the data set by using the most reliable data set. For example, all of the thermal data was ranked in classes "a" through "c" according to the reliability of the source. Published data was ranked "a", WATSTORE and oil well temperatures ranked "b", and unconfirmed rumors, etc., ranked

"c". The class "a" data were given priority over the other classes.

2. In the case of multiple discharge points from a hot spring area, the hottest spring was used. Nearby springs were considered to represent separate springs if they were far enough apart to plot as separate points at a scale of 1:500,000.
3. All points, particularly those of quality "b" and "c", were removed from the data set if they appeared to be in error. The most common instances of these deletions were wells with temperatures reported between 60°C and 70°C, and located in areas which were studied by, but not reported by, geothermal investigators. It was assumed that these temperatures were measured in °F and inadvertently reported in units of °C.
4. In most cases, rumors (meaning no measured temperature data) have not been included in the data set unless they represent areas reasonably well entrenched in the geothermal literature.

Treatment of Oil Well Data

By virtue of their extreme depth, most oil wells have very high bottom hole temperatures and reporting these high temperatures in a geothermal context represents a potentially serious misuse of the data. Clearly well depth and temperature gradient data must be taken into account. For New Mexico, the problem has been compounded by the fact that most oil fields are located in the non-geothermal portions of the state. In order to insure that the oil well temperature data included in the catalogue of thermal waters actually reflects geothermal activity, we report only wells whose temperature gradient exceeds 40°C/Km. This value was assigned in the

following manner. Temperature gradients were calculated by subtracting the mean surface temperature ($^{\circ}\text{C}$) from the bottom hole temperature ($^{\circ}\text{C}$) and dividing by depth (Km). A mean gradient and standard deviation were then calculated and wells having a gradient greater than one standard deviation above the mean were considered to be geothermal and have been included in the geothermal data base. For New Mexico oil well data, a gradient of 40°C/Km is one deviation above the mean. To check the significance of this value, the same approach was applied to the highly accurate and extensive temperature data set of Shearer and Reiter (1978). In this case, not only was the same cutoff gradient ($\sim 40^{\circ}\text{C/Km}$) obtained but the condition that most of the high gradients actually reflect geothermal activity was confirmed. These determinations were possible because the data of Shearer and Reiter (1978) also include heat flow values, the single most reliable parameter in assessing geothermal potential.

20 $^{\circ}\text{C}$ Isotherm

The U. S. Department of Energy has determined that the minimum temperature for designating a well as "geothermal" is 20°C . This temperature is realistic for most parts of the country, but for New Mexico it creates a special problem. In southern New Mexico, nearly all water wells exceed 20°C so that including these wells in the data base creates a data base that reflects water well distribution and not geothermal activity. To eliminate this problem, wells are considered to be geothermal in New Mexico if they exceed 30°C . Wells in the 20 to 30°C range are not depicted individually but are shown schematically in Figure 1. South of the east-west trending line, all wells drilled to the water table are expected to exceed 20°C , with the obvious exceptions being the mountainous

Figure 1. Locations in New Mexico where any well drilled into the water table should exceed 20°C.

areas such as the Sacramento Mountains. The distribution of 20 to 30°C waters in New Mexico is treated more thoroughly in Chapter 1, Part 1 of this report.

Catalogue of Thermal Waters

Table 1 lists the thermal waters in New Mexico as of the editing of January 1980. The file is still incomplete as several additional oil well temperatures will be included and the final editing of the DOE/NOAA/NMEI public map may result in some additional deletions. Thus, the results shown in Table 1 should be used with caution. After the final editing, a list was submitted to the NMEI and to the USGS for inclusion into GEOTHERM. Table 2 contains a list of all wells in New Mexico listed in the USGS WATSTORE file (file dated summer, 1978) that exceed 30°C. This list has not been edited and may contain errors.

References

Shearer, C., and Reiter, M., 1978, Basic heat flow data in New Mexico, N. Mex. Bur. Mines and Min. Res., Open-file Rpt. 93.

Table 1. A preliminary list of thermal wells and springs submitted to NOAA for inclusion in the public and scientific geothermal maps of New Mexico.

Location		Temp.	Depth	Location		Temp.	Depth
Lat.	Long.	°C	M	Lat.	Long.	°C	M
32°10.5'	108°52.0'	35	10	35°52.5'	106°42.0'	202	3066
32°10.5'	108°51.0'	121	2256	35°33.0'	108°50.5'	39	583
32°25.0'	108°59.0'	35	136	35°56.0'	107°58.0'	32	293
32°56.0'	108°36.0'	30	11	35°53.0'	107°25.0'	48	686
32°59.0'	108°36.0'	33	91	35°50.0'	107°25.0'	83	1584
35°59.0'	103°18.0'	40	320	35°44.0'	107°42.4'	47	497
35°35.0'	103°27.0'	32	336	35°42.0'	108°03.0'	42	614
35°07.0'	104°19.0'	32	384	35°43.0'	107°44.5'	40	567
32°04.5'	106°37.0'	36	219	35°43.0'	107°42.0'	56	904
32°01.0'	106°37.0'	32	244	35°36.5'	107°54.5'	44	639
32°03.0'	106°59.5'	34	131	36°31.5'	107°56.0'	49	648
32°01.5'	106°53.5'	33	172	36°30.0'	108°10.0'	38	399
31°58.0'	106°58.0'	38	55	36°28.0'	108°07.0'	34	398
36°29.5'	107°24.0'	116	2318	36°30.0'	108°03.0'	33	436
36°28.5'	107°22.0'	44	666	36°30.5'	107°47.5'	40	635
36°31.0'	107°12.0'	89	1917	36°23.5'	108°04.0'	34	396
36°29.0'	106°51.0'	54	904	36°22.0'	108°11.0'	34	427
36°26.5'	107°10.5'	84	1202	36°15.0'	108°06.0'	31	383
36°24.0'	107°15.5'	94	1203	32°22.0'	107°40.0'	47	320
36°23.5'	107°27.5'	59	1097	33°34.0'	107°36.0'	36	250
36°23.5'	107°21.0'	76	764	36°46.0'	105°58.0'	33	330
36°22.0'	107°35.0'	46	818	32°30.0'	106°06.0'	32	370
36°22.5'	107°25.0'	50	764	33°45.0'	107°49.0'	32	350
36°20.5'	107°30.0'	43	707	32°10.0'	109°02.0'	36	310
36°19.5'	107°17.0'	49	893	36°45.0'	104°53.0'	73	1350
36°19.0'	107°20.0'	81	1293	32°32.0'	106°25.0'	32	300
36°18.0'	107°34.0'	74	1539	35°53.0'	106°40.0'	34	170
36°18.0'	107°09.0'	56	959	35°56.0'	106°40.0'	36	160
36°16.5'	107°05.0'	56	978	35°58.0'	106°38.0'	45	210
36°16.0'	107°18.0'	46	777	35°54.0'	106°40.0'	96	730
36°14.0'	107°03.0'	56	932	34°04.0'	106°57.0'	43	61
36°11.5'	107°28.0'	66	854	32°09.0'	107°03.0'	33	240
36°10.5'	107°15.5'	43	732	32°22.0'	106°40.0'	34	350
35°53.0'	107°16.0'	32	304	32°08.0'	106°51.0'	35	490
35°46.0'	107°14.0'	32	366	32°48.0'	106°52.0'	35	300

Table 1. (continued).

Location		Temp.	Depth	Location		Temp.	Depth
Lat.	Long.	°C	M	Lat.	Long.	°C	M
32°34.0'	108°01.4'	41	33	33°11.9'	108°12.3'	61	-
32°40.2'	108°02.1'	62	158	34°02.8'	106°57.0'	32	-
32°15.0'	107°34.0'	39	338	35°02.4'	104°40.9'	35	-
35°30.3'	108°34.2'	61	592	35°03.0'	104°43.3'	32	-
35°53.8'	108°38.1'	35	243	35°03.1'	106°43.6'	30	-
35°58.3'	106°33.6'	38	spr	35°04.7'	106°43.9'	34	-
35°56.3'	106°38.7'	56	spr	35°04.8'	106°43.3'	40	-
35°54.5'	106°36.9'	70	spr	35°05.0'	106°44.3'	-	-
35°51.0'	106°37.7'	42	spr	35°05.1'	106°43.4'	30	-
35°46.6'	106°41.3'	74	spr	35°04.9'	106°44.9'	30	-
35°47.7'	106°41.2'	47	spr	35°21.0'	106°40.2'	32	-
35°49.2'	106°37.6'	32	spr	35°37.5'	108°47.5'	46	367
35°35.5'	106°45.2'	51	spr	35°46.2'	106°41.5'	49	-
35°38.0'	106°51.0'	46	168	35°46.2'	106°41.5'	58	-
35°40.5'	106°53.0'	52	612	35°46.3'	106°41.4'	71	-
36°16.0'	106°49.0'	-	-	35°47.5'	106°41.2'	50	-
32°48.0'	108°36.0'	-	-	35°49.2'	106°37.6'	31	-
32°10.8'	106°40.1'	-	-	35°51.1'	108°40.1'	35	-
31°42.0'	108°49.0'	-	-	35°52.9'	106°40.2'	76	-
31°56.4'	106°39.3'	33	213	35°55.4'	107°29.6'	65	-
32°03.2'	106°52.3'	34	131	36°00.3'	107°22.6'	33	-
32°05.3'	104°18.9'	33	-	36°03.7'	107°51.9'	42	-
32°08.4'	106°39.9'	31	-	36°15.5'	108°19.4'	61	-
32°10.7'	103°59.8'	32	-	36°34.3'	108°33.8'	31	-
32°11.9'	104°00.6'	31	-	36°46.5'	108°26.2'	33	-
32°13.1'	104°00.1'	55	-	36°47.1'	108°26.4'	33	-
32°13.3'	104°00.8'	32	-	36°47.6'	108°25.8'	34	-
32°15.9'	106°43.4'	36	148	36°48.1'	108°25.2'	31	-
32°30.1'	106°45.0'	52	-	36°48.7'	108°25.8'	30	-
32°33.3'	107°59.7'	52	-	33°16.7'	107°33.7'	31	spr
32°34.2'	107°59.8'	54	-	34°48.5'	107°05.4'	30	spr
32°38.0'	107°19.0'	31	-	32°38.6'	108°07.6'	36	spr
32°38.7'	108°07.7'	31	269	33°17.8'	108°16.8'	36	spr
32°45.0'	107°50.1'	60	-	33°17.6'	108°15.9'	37	spr
32°49.4'	106°37.9'	31	-	33°16.6'	108°15.6'	34	spr

Table 1. (continued).

Location		Temp.	Depth	Location		Temp.	Depth
Lat.	Long.	°C	M	Lat.	Long.	°C	M
32°48.0'	106°54.0'	36	300	33°12.0'	108°12.6'	66	spr
32°27.0'	106°36.0'	49	840	33°14.0'	108°14.2'	65	spr
32°27.0'	106°36.0'	52	910	33°09.8'	108°12.7'	44	spr
32°25.0'	106°07.0'	41	600	32°13.7'	108°30.7'	33	spr
34°02.0'	107°48.0'	88	1463	33°06.5'	108°29.0'	74	spr
32°15.8'	107°00.8'	36	320	32°52.6'	108°35.0'	31	spr
32°10.7'	106°40.2'	29	122	33°17.0'	108°15.8'	31	spp
32°08.8'	106°39.3'	32	76	33°17.4'	108°15.9'	37	spr
32°08.4'	106°52.1'	31	209	31°50.5'	107°31.2'	30	-
32°04.0'	106°36.9'	31	153	33°16.4'	108°15.0'	34	spr
31°49.5'	106°38.0'	31	306	35°39.2'	105°17.4'	58	spr
32°27.7'	106°27.1'	29	310	36°18.3'	106°03.4'	56	-
32°26.7'	106°26.6'	29	240	36°18.3'	106°03.4'	44	spr
32°16.9'	106°25.2'	30	320	36°19.4'	105°36.5'	34	spr
32°05.0'	106°09.4'	61	230	36°30.6'	105°43.2'	38	spr
32°04.6'	106°10.6'	50	130	36°31.7'	105°42.9'	41	spr
32°04.2'	106°09.1'	71	140	31°48.1'	107°46.9'	31	-
32°36.4'	106°58.8'	52	150	32°46.8'	106°09.0'	34	-
32°37.9'	106°59.6'	36	175	32°36.4'	107°11.7'	31	spr
32°36.4'	106°58.8'	53	150	32°47.7'	107°16.6'	33	spr
32°15.8'	106°43.8'	41	80	32°18.4'	108°19.5'	32	spr
32°15.5'	106°43.8'	42	100	33°15.7'	108°13.7'	34	spr
32°22.9'	106°41.5'	33	340	33°12.8'	108°13.7'	65	spr
32°00.9'	106°53.7'	31	115	33°13.5'	108°13.2'	32	183
32°17.0'	106°43.5'	48	145	32°58.7'	108°35.5'	35	91
32°17.2'	106°43.0'	62	300	33°42.5'	109°01.3'	33	spr
32°17.0'	106°43.6'	50	360	33°11.1'	108°10.2'	52	spr
32°38.0'	107°00.0'	34	180	33°25.0'	106°54.0'	34	410
33°49.8'	108°47.9'	37	spr	32°41.5'	107°02.0'	56	-
33°14.5'	108°52.8'	49	spr	33°04.0'	107°18.0'	33	458
32°08.7'	108°49.9'	85	-	32°15.8'	106°58.8'	32	366
32°30.1'	106°55.7'	53	-	32°16.1'	107°01.0'	36	320
33°08.1'	107°15.2'	45	spr	32°05.4'	106°51.9'	-	-
34°02.2'	106°56.2'	34	spr	32°08.2'	106°52.2'	31	-
33°45.8'	107°21.0'	30	-	32°16.1'	106°41.0'	-	-
32°33.3'	107°59.7'	34	spr	32°04.1'	106°36.8'	31	153
32°44.9'	107°50.1'	58	spr	32°00.2'	106°07.4'	-	-

Table 1. (continued).

Location		Temp.	Depth
Lat.	Long.	°C	M
35°53.0'	106°40.5'	196	2900
36°29.5'	108°21.0'	81	1700
36°31.5'	107°20.5'	123	2575
36°05.0'	107°30.5'	63	1356
36°00.5'	107°22.0'	61	1266
35°47.0'	107°14.5'	68	1408
35°00.5'	106°58.0'	58	1105
32°34.0'	104°12.5'	91	1335
35°26.0'	107°53.0'	46	-
35°33.2'	106°54.3'	23	spr
33°23.3'	106°55.6'	24	spr
33°23.6'	107°04.9'	29	spr
32°48.8'	108°35.5'	24	spr
33°16.4'	108°15.8'	26	spr
32°15.0'	104°25.0'	20	spr
32°27.6'	104°28.9'	26	spr
32°57.2'	107°34.8'	34	spr

Table 2. An unedited list of wells in New Mexico of or exceeding 30°C from the USGS file WAT-STORE.

Location		Temp	Depth	Location		Temp.	Depth
Lat.	Long.	°C	Ft. *	Lat.	Long.	°C	Ft.
31.0625	103.4792	30	410	32.0883	104.3150	33	-
31.0625	103.4792	30	-	32.1394	106.6647	31	-
31.1042	103.4375	30	128	32.1522	106.6544	30	250
31.1042	103.4375	30	350	32.1525	106.6547	32	-
31.1042	104.6458	31	500	32.1783	103.9972	30	-
31.1042	104.6875	31	387	32.1783	103.9972	30	-
31.1875	103.6875	30	1390	32.1783	103.9972	30	-
31.1875	103.6875	30	920	32.1783	103.9972	30	-
31.2292	103.8125	31	1305	32.1783	103.9972	32	-
31.2708	103.6458	33	800	32.1986	104.0097	30	-
31.2708	103.6458	33	800	32.1986	104.0097	31	-
31.2708	103.7292	33	350	32.2075	109.1833	32	2000
31.3125	103.6458	33	575	32.2075	109.1833	32	2000
31.3125	103.6875	33	130	32.2083	110.9256	30	1400
31.3542	103.6458	30	532	32.2180	104.0022	30	-
31.3542	103.6458	33	1284	32.2180	104.0022	55	-
31.3542	103.6458	31	300	32.2222	104.0139	32	-
31.3542	103.6458	30	190	32.2625	107.0144	36	-
31.3542	103.6458	31	300	32.2653	106.7228	36	486
31.3542	103.6875	30	-	32.2697	106.7217	43	-
31.3542	103.6875	30	1096	32.3958	103.7505	30	-
31.3542	103.6875	30	1205	32.3958	103.7505	31	4882
31.3542	103.6875	30	900	32.3964	103.7505	32	4880
31.3542	103.6875	30	-	32.5003	106.7503	52	-
31.3542	103.6875	30	1205	32.5547	107.9950	52	-
31.3542	103.6875	30	1220	32.5692	107.9972	54	-
31.8125	106.1875	30	417	32.6333	107.3167	31	-
31.8125	106.1875	31	-	32.6444	108.1278	31	881
31.8125	106.2292	33	640	32.7492	107.8344	60	-
31.8125	106.3125	30	500	32.7955	107.2767	34	-
31.9394	106.6547	30	700	32.8236	106.6319	31	-
31.9394	106.6547	33	700	33.1278	107.2531	40	-
32.0047	106.6097	31	-	33.1986	108.2044	61	-
32.0525	106.8711	34	430	33.2447	108.8811	35	-
32.0675	106.6147	31	-	33.6686	106.6533	80	-

* - Denotes no data available

Table 2. (continued).

Location		Temp.	Depth	Location		Temp.	Depth
Lat.	Long.	°C	Ft. *	Lat.	Long.	°C	Ft.
34.0467	106.9503	32	-	36.7850	108.4406	33	-
35.0405	104.6811	30	-	36.7936	108.4297	34	-
35.0405	104.6811	35	-	36.8022	108.4205	31	-
35.0500	104.7225	32	-	36.8119	108.4305	30	-
35.0522	106.7261	30	-	34.8536	106.7780	32	16346
35.0786	106.7319	34	-	34.8931	108.4147	36	3229
35.0797	106.7211	40	-				
35.0814	106.7483	30	-				
35.0825	106.7383	31	1180				
35.0853	106.7236	30	-				
35.3494	106.6694	32	-				
35.6250	108.7917	32	-				
35.6325	108.7919	32	2148				
35.6456	106.8886	52	-				
35.7703	106.6922	49	-				
35.7706	106.6914	58	-				
35.7717	106.6906	71	-				
35.7719	106.6903	72	-				
35.7911	106.6864	50	-				
35.7914	106.6861	46	-				
35.8200	106.6267	31	-				
35.8511	108.6680	35	-				
35.8817	106.6700	76	-				
35.9225	107.4928	65	-				
35.9397	106.6433	40	-				
36.0047	107.3775	33	-				
36.0536	107.7928	48	-				
36.0536	107.7928	57	5076				
36.0622	107.8656	42	-				
36.2578	108.3228	61	-				
36.3044	106.0522	40	-				
36.3236	105.6055	32	-				
36.5083	105.7236	34	-				
36.5714	108.5636	31	-				
36.7753	108.4361	33	-				

* - Denotes no data available

Chapter 2

Water Quality of Geothermal Waters

Part 1

Distribution of Saline Water*

Introduction

There are four basic reasons to include salinity studies as part of a routine statewide geothermal evaluation. The first concerns the plethora of governmental regulations regarding the handling and disposal of geothermal fluids. Even if the geothermal fluid poses no real or suspected threat to the environment, the salinity of the fluid must be known in order to comply with the regulatory process. Secondly, in a few cases, a geothermal fluid may have a legitimate potential impact on the environment. Such fluids require special handling and special surface equipment may be required. The nature of the impact must be known at an early stage of development so that the extra cost of special handling can be incorporated into the economics of development. Third, some geothermal fluids may be corrosive because of high hydrogen sulphide concentrations or may scale hardware due to high silica or carbonate contents. Routine chemical analysis of geothermal fluids will help to predict these problems and permit the selection of proper materials for surface hardware and the proper method of treating the geothermal fluid. Finally, geothermal resources associated with large, closed basins may be very saline. Such areas are ideal targets for the production of new sources of fresh water by geothermal desalination.

*The principal author of Chapter 2, Part 1 is Dr. Chandler A. Swanberg, Associate Professor of Physics and Earth Sciences, New Mexico State University.

The information necessary for evaluation of these problems is presented by Swanberg (1980) and is summarized in Figure 1.

Conclusions

Swanberg (1980) reports the salinity and chemical constituents of New Mexico's thermal waters and also the salinity of the state's non-thermal waters. On the basis of these data, the following conclusions seem justified.

1. The only thermal area in New Mexico associated with high levels of objectionable chemical constituents is the Valles Caldera and adjacent areas. Hot springs in these areas contain higher than normal amounts of volcanic gases and trace elements such as hydrogen sulfide, arsenic, mercury, boron, fluoride, and several others.
2. Several thermal areas including those in the Tularosa Basin may be associated with geothermal brine. These areas are ideal for fresh water production by geothermal desalination.
3. Most thermal waters in New Mexico have salinities (total dissolved solids) in the range of 1000 to 3000 mg/l. While such waters are not particularly harmful to the environment, legal constraints may require special handling.
4. Several thermal areas including those in the Gila National Forest and in the Socorro area are remarkably fresh (< 400 mg/l TDS).

Figure 1. Salinity (total dissolved solids) of groundwaters in New Mexico and west Texas.

Reference

Swanberg, C. A., 1980, Chemistry, origin, and geothermal potential of thermal and non-thermal groundwaters in New Mexico, Final Rpt. U. S. G. S. Grant #14-08-0001-G-255, N. Mex. Dept. Energy and Min. Grant ERB-75-117, April, 1980.

Part 2

Water Quality of Geothermal Waters*

This Chapter 2, Part 2 is an open-file report dated 16 May 1978 and the information contained herein is preliminary and subject to correction. Neither the compiler, the New Mexico Energy Institute, nor the funding agencies are responsible for its content.

The geochemical data from New Mexico geothermal waters are reported in the following tables:

- Table 1. Temperature and location of springs and wells in New Mexico and west Texas.
- Table 2. Major cations and anions for springs and wells in New Mexico and west Texas.
- Table 3. Analysis of iron, fluoride, boron, phosphorous and silica for selected thermal waters in New Mexico and west Texas.
- Table 4. Analysis of nitrogen, nickel, lead, antimony, selenium, strontium and zinc for selected thermal waters in New Mexico and west Texas.
- Table 5. Analysis of cadmium, cobalt, chromium, copper, mercury, hydrogen sulfide, lithium, manganese, molybdenum, ammonium, silver, aluminum, arsenic, barium and bromide for selected waters in New Mexico and west Texas.
- Table 6. Additional raw data to supplement preceding data.

*The material contained in Chapter 2, Part 2 was compiled by Dr. Chandler A. Swanberg, Associate Professor of Physics and Earth Sciences, New Mexico State University.

Table 1. Temperature and location of springs and wells in New Mexico and west Texas.

Field #	Lab #	T ₁	T ₂	T ₃	L ₁	L ₂	L ₃	Name
		°C	°C	°C				
J1	N/A	25.6	2.8	51.8	Reading Mountain	108°21.5'W 32°53.4'N	T16S R15W Sec 26 SE 1/4 NW 1/4	Allen Spring
J2	N/A	36.7	51.8	97.4	Dillon Mountain	108°47.9'W 33°49.8'N	T5S R19W Sec 35 NW 1/4 NW 1/4 NW 1/4	Upper Frisco Hot Springs
J3	N/A	43.3	148.6	121.9	Wilson Mountain	108°52.7'W 33°14.6'N	T12S R20W Sec 23 SW 1/4 NE 1/4 NW 1/4	Lower Frisco Hot Springs
J4	N/A	40.0	97.0	114.3	Wilson Mountain	108°52.6'W 33°14.9'N	T12S R20W Sec 23 NW 1/4 SW 1/4	Lower Frisco Hot Springs
J5	N/A	48.9	147.9	131.9	Wilson Mountain	108°52.8'W 33°14.5'N	T12S R20W Sec 23 SW 1/4 NE 1/4 SW 1/4	Lower Frisco Hot Springs
J6	N/A	21.1	38.9	74.1	Buckhorn (no map)	108°41.5'W 33°1.6'N	T15S R18W Sec 3 SW 1/4 NW 1/4 NW 1/4	Well
J7	N/A	25.0	53.0	78.4	Cliff	108°37.9'W 32°58.5'N	T15S R17W Sec 30 NE 1/4 NE 1/4 NE 1/4	Warm Spring
P1	N/A	23.0	38.1	81.2	Swallow Fork Peak	108°47.6'W 32°8.7'N	T25S R19W Sec 10 NW 1/4 SW 1/4 SW 1/4	Road Well
P2	N/A	85.0	172.9	160.1	Swallow Fork Peak	108°49.9'W 32°8.7'N	T25S R19W Sec 7 NE 1/4 SW 1/4 SE 1/4	Hot Well
P3	N/A	81.0	168.5	158.2	Swallow Fork Peak	108°49.9'W 32°8.9'W	T25S R19W Sec 7 NE 1/4 NW 1/4 SE 1/4	McCants Well
P4	N/A	71.0	158.8	145.5	Swallow Fork Peak	108°50.4'W 32°8.7'N	T25S R19W Sec 7 NW 1/4 SE 1/4 SW 1/4	Well

T₁ = Actual Temperature

L₁ = Map or Quadrangle Name

T₂ = NaKCa Estimated Temperature

L₂ = Latitude and Longitude Location

T₃ = Silica Estimated Temperature

L₃ = Township & Range Location

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
P5	N/A	22.0	60.0	94.2	Swallow Fork Peak	106°50.9'W 32° 8.1'N	T25S R20W Sec 13 NE 1/4 NW 1/4 SE 1/4	Well
P10	N/A	23.0	71.1	111.1	Swallow Fork Peak	108°49.7'W 32°13.6'N	T24S R19W Sec 7 SE 1/4 SE 1/4 NE 1/4	Hill Well
P13	N/A	19.0	49.3	121.2	Swallow Fork Peak	106°52.4'W 32°13.7'N	T24S R20W Sec 11 SW 1/4 NE 1/4 SW 1/4	Well
P14	N/A	20.0	38.2	100.3	Swallow Fork Peak	108°52.8'W 32°10.1'N	T24S R20W Sec 34 SE 1/4 SE 1/4 SE 1/4	Well
P15	N/A	24.0	57.4	85.0	Table Top Mountain	108°50.7'W 32°6.1'N	T25S R20W Sec 25 SE 1/4 NE 1/4 NE 1/4	Well
P20	N/A	22.0	36.6	102.2	Cotton City	108°54.0'W 32°4.8'N	T26S R20W Sec 5 SE 1/4 SE 1/4 SE 1/4	Well
P22	N/A	22.0	41.6	95.2	Table Top Mountain	108°52.9'W 32°4.1'N	T26S R20W Sec 3 SW 1/4 SW 1/4 SW 1/4	Well
P23	N/A	24.0	45.6	78.4	Swallow Fork Peak	108°48.8'W 32°12.2'N	T24S R19W Sec 2 SE 1/4 NE 1/4 NW 1/4	National Well
P24	N/A	N/A	156.0	161.0	Swallow Fork Peak	108°50.7'W 32°10.9'N	T24S R20W Sec 25 SE 1/4 SE 1/4 SE 1/4	Well
P25	N/A	23.0	50.1	85.0	Swallow Fork Peak	108°52.8'W 32°9.1'N	T25S R20W Sec 10 NE 1/4 NE 1/4 NE 1/4	Well
W1	N/A	28.0	161.7	117.8	Dona Ana Co.	106°59.4'W 32°9.2'N	T25S R1W Sec 7 NW 1/4 NW 1/4	Well
W2	N/A	N/A	165.4	120.9	Dona Ana Co.	106°58.7'W 32°4.2'N	T26S R1W Sec 7 NE 1/4 NW 1/4	Well
W3	N/A	N/A	152.9	106.8	Dona Ana Co.	106°54.7'W 32°55.6'N	T27S R1W Sec 26 SE 1/4 SW 1/4	Well
W4	N/A	N/A	185.6	109.5	Dona Ana Co.	105°50.2'W 31°55.0'N	T27S R1E Sec 34 SW 1/4 NW 1/4	Well
W5	N/A	22.0	163.5	99.0	Dona Ana Co.	107°2.3'W 32°16.6'N	T23S R2W Sec 27 SW 1/4 NW 1/4	Well
W6	N/A	22.0	153.2	114.6	Dona Ana Co.	107°1.3'W 32°17.4'N	T23S R2W Sec 23 SW 1/4 SW 1/4	Well
W7	N/A	21.0	42.4	89.3	Dona Ana Co.	107°7.5'W 32°21.2'N	T22S R3W Sec 35 NW 1/4 NW 1/4	Well
W8	N/A	21.0	29.0	99.0	Dona Ana Co.	107°9.3'W 32°23.2'N	T22S R3W Sec 21 NW 1/4 NE 1/4	Well
W9	N/A	N/A	133.8	14.1	Dona Ana Co.	107°4.8'W 32°26.1'N	T21S R2W Sec 31 SE 1/4 SW 1/4	Well
W10	N/A	N/A	84.6	33.3	Dona Ana Co.	106°56.6'W 32°41.8'N	T18S R1W Sec 33 SE 1/4 SE 1/4	Well
W11	N/A	23.0	28.4	77.2	Dona Ana Co.	106°49.4'W 32°42.5'N	T18S R1E Sec 27 SE 1/4 SW 1/4	Red Lake Well
W12	N/A	21.0	31.8	74.4	Dona Ana Co.	106°47.2'W 32°41.5'N	T19S R1E Sec 1 NE 1/4 NE 1/4	Middle Well
W13	N/A	24.0	32.9	75.7	Dona Ana Co.	106°40.6'W 32°38.8'N	T19S R3E Sec 19 NW 1/4 NE 1/4	Well

Table 1. (continued)

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
W14	N/A	22.0	39.2	69.3	Dona Ana Co.	106°40.5'W 32°34.5'N	T20S R3E Sec 18 NE 1/4 NW 1/4	Taylor Well
W15	N/A	23.0	65.2	100.0	Dona Ana Co.	106°45.0'W 32°32.2'N	T20S R2E Sec 28 SW 1/4 SW 1/4	Well
W16	N/A	26.0	40.9	51.3	Dona Ana Co.	106°48.6'W 32°34.3'N	T20S R1E Sec 14 NW 1/4 SE 1/4	Well
W17	N/A	N/A	43.2	48.8	Dona Ana Co.	106°50.3'W 32°39.6'N	T19S R1E Sec 16 NE 1/4 NE 1/4	Wagoner Well
W18	N/A	24.0	41.7	117.0	Dona Ana Co.	106°55.8'W 32°38.8'N	T19S R1W Sec 22 NW 1/4 NE 1/4	Well
W19	N/A	N/A	95.5	94.9	Dona Ana Co.	107°00.6'W 32°45.2'N	T19S R2W Sec 11 SE 1/4 SW 1/4	Well
W20	N/A	N/A	55.0	115.5	Dona Ana Co.	107°8.1'W 32°34.2'N	T20S R3W Sec 15 NE 1/4 SW 1/4	Well
W21	N/A	17.0	57.2	117.0	Dona Ana Co.	107°6.7'W 32°34.4'N	T20S R3W Sec 14 NE 1/4 NE 1/4	Well
W22	N/A	21.0	47.9	114.6	Dona Ana Co.	107°9.4'W 32°35.8'N	T20S R3W Sec 4 SW 1/4 NE 1/4	Well
W23	N/A	22.0	10.3	93.7	Dona Ana Co.	107°6.0'W 32°11.5'N	T24S R3W Sec 25 SE 1/4 NW 1/4	Well
W24	N/A	27.0	113.1	62.5	Dona Ana Co.	107°4.9'W 32°1.2'N	T26S R2W Sec 30 NE 1/4 SW 1/4	Well
W25	N/A	27.0	204.0	93.7	Dona Ana Co.	107°1.2'W 31°59.6'W	T27S R2W Sec 2 NW 1/4 SE 1/4	Well
W26	N/A	22.0	127.8	105.0	Dona Ana Co.	106°57.9'W 31°55.4'N	T27S R1W Sec 32 NW 1/4 NE 1/4	Well
W27	N/A	28.0	186.3	113.0	Dona Ana Co.	106°50.2'W 31°55.0'N	T27S R1E Sec 34 SW 1/4 NW 1/4	Well
W28	N/A	26.0	151.0	123.1	Dona Ana Co.	106°57.6'W 32°2.2'N	T26S R1W Sec 20 NE 1/4 NE 1/4	Well
W29	N/A	18.0	8.8	84.1	Dona Ana Co.	106°37.4'W 32°20.3'N	T23S R3E Sec 3 NE 1/4 SW 1/4	Well
W30	N/A	N/A	19.4	91.5	Dona Ana Co.	106°35.9'W 32°25.6'N	T22S R3E Sec 2 SE 1/4 SE 1/4	Well
W31	N/A	N/A	92.8	91.5	Dona Ana Co.	106°45.1'W 31°56.9'N	T27S R2E Sec 20 NE 1/4 NE 1/4	Well
W32	N/A	27.0	131.7	104.0	Dona Ana Co.	106°42.7'W 31°51.7'N	T28S R2E Sec 23 NE 1/4 NW 1/4	Well
W33	N/A	N/A	174.7	133.5	Dona Ana Co.	107°1.7'W 31°47.3'N	T29S R2W Sec 15 NE 1/4 NW 1/4	Well
W34	N/A	N/A	202.6	128.8	Dona Ana Co.	107°6.5'W 31°47.2'N	T29S R3W Sec 13 NW 1/4 SW 1/4	Well
W35	N/A	17.0	171.8	91.5	Dona Ana Co.	107°8.6'W 31°49.1'N	T29S R3W Sec 3 NW 1/4 NW 1/4	Well
W36	N/A	27.0	162.0	100.0	Dona Ana Co.	107°17.0'W 31°47.5'N	T29S R4W Sec 18 NE 1/4 NE 1/4	Well

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
B1	N/A	N/A	51.0	98.2	Dona Ana County	106°49.2'W 32°28.2'N	T21S R1E Sec 22 NE 1/4 SE 1/4	Cleofas Wells
B2	N/A	53.0	223.4	118.1	Dona Ana County	106°55.7'W 32°30.1'N	T21S R1W Sec 10 NE 1/4 SW 1/4	Radium Springs (well)
B3	N/A	N/A	84.7	86.4	Dona Ana County	106°56.0'W 32°29.6'N	T21S R1W Sec 10 SE 1/4 NE 1/4	Well
B4	N/A	N/A	49.1	113.6	Dona Ana County	106°55.8'W 32°38.8'N	T19S R1W Sec 22 NW 1/4 NE 1/4	Well
B5	N/A	N/A	156.2	81.2	Dona Ana County	107°16.6'W 32°47.7'N	T17S R4J Sec 29 SW 1/4 NE 1/4	Derry Spring
B6	N/A	N/A	155.7	82.5	Dona Ana County	107°16.6'W 32°47.6'N	T17S R4W Sec 29	Derry Spring
B7	N/A	N/A	49.9	77.9	Dona Ana County	107°16.4'W 32°48.7'N	T17S R4W Sec 20 SE 1/4 NW 1/4	Well
B8	N/A	N/A	78.7	96.2	Dona Ana County	106°59.9'W 32°34.1'N	T20S R2W Sec 13 SE 1/4 NW 1/4	Well
B9	N/A	45.0	175.6	96.2	Dona Ana County	107°15.2'W 32°8.1'N	T13S R4W Sec 33 SE 1/4 NW 1/4	Well (Mineral Bat Bluckstore)
B10	N/A	41.0	178.1	96.2	Dona Ana County	107°14.9'W 33°8.1'N	T13S R4W Sec 33 NE 1/4 SE 1/4	Well (Mineral Bath-Sierra)
B11	N/A	41.0	179.5	96.2	Dona Ana County	107°14.5'W 33°8.0'N	T13S R4W Sec 34 SW 1/4 NE 1/4	Warm Spring
B12	N/A	N/A	150.2	88.6	Dona Ana County	107°33.8'W 33°16.7'N	T12S R7W Sec 9 NW 1/4 SW 1/4	Warm Spring
B13	N/A	34.0	58.5	72.5	Dona Ana County	106°56.2'W 34°2.2'N	T3S R1W Sec 22 NW 1/4 SW 1/4	Sedillo Spring
B14	N/A	N/A	61.3	65.8	Dona Ana County	106°56.2'W 34° 2.8'N	T3S R1W Sec 17 SW 1/4 NW 1/4	Cook Spring
B15	N/A	N/A	48.2	82.2	Dona Ana County	107°21.4'W 33°14.1'N	T12S R5W Sec 28 SE 1/4 NW 1/4	Well
B16	N/A	N/A	28.1	96.2	Dona Ana County	107°40.4'W 33°30.3'N	T9S R8W Sec 28 NW 1/4 NE 1/4	Well
B17	N/A	28.0	67.2	86.2	Dona Ana County	107°36.1'W 33°34.4'N	T8S R7W Sec 31 SE 1/4 NW 1/4	Spring
B18	N/A	21.0	72.6	84.9	Dona Ana County	107°35.9'W 33°34.4'N	T8S R7W Sec 31 SE 1/4 SE 1/4	Spring
B19	N/A	41.0	176.8	81.2	Dona Ana County	107°15.2'W 33°8.1'N	T13S R4W Sec 33 SE 1/4 NW 1/4	Yucca Springs
B20	SW19	N/A	83.3	75.0	Dona Ana County	107°00.6'W 33°03.8'N	T14S R2W Sec 29 NE 1/4 SE 1/4	Well
B21	SW20	N/A	96.2	35.9	Dona Ana County	106°56.2'W 33°17.4'N	T11S R2W Sec 3 SW 1/4 SW 1/4	Well
B22	SW21	N/A	81.9	55.3	Dona Ana County	106°53.5'W 33°28.6'N	T9S R1E Sec 36 SE 1/4 SE 1/4	Malpais Well
B23	SW22	18.0	14.6	78.2	Dona Ana County	106°52.4'W 33°25.1'N	T10S R1E Sec 29 NW 1/4 NE 1/4	Chavez Well
B24	SW23	24.0	65.5	75.0	Dona Ana County	106°55.6'W 33°23.3'N	T10S R1W Sec 29 NW 1/4 NW 1/4	Tucson Spring

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
B25	SW24	29.0	65.7	69.8	Dona Ana County	106°35.6'W 33°34.4'N	T85 R2W Sec 31 NE 1/4 SE 1/4	Ojo Caliente
B26	SW25	4.0	31.2	88.0	Dona Ana County	107°31.7'W 33°53.1'N	T55 R7W Sec 11 NE 1/4 SE 1/4	Spring
B27	SW26	4.0	31.5	88.0	Dona Ana County	107°32.2'W 33°54.0'N	T55 R7W Sec 2 SW 1/4 NE 1/4	Spring
B28	SW27	30.0	12.5	101.9	Dona Ana County	107°21.0'W 33°45.8'N	T65 R5W Sec 27 SW 1/4 NE 1/4	Well
Gila 1	SW28	17.7	36.1	94.0	Las Cruces 1:250,000	107°57.5'W 32°26.7'N	T21S R11W Sec 15, SE 1/4	Well
Gila 2	SW29	58.8	78.4	97.2	Dwyer	107°59.7'W 32°33.3'N	T20S R11W Sec 20 NW 1/4 SE 1/4	Faywood Hot Spring
Gila 3	SW30	21.3	47.0	92.8	Las Cruces 1:250,000	107°58.1'W 32°33.5'N	T20S R11W Sec 22 NW 1/4	Well
Gila 4	SW31	58.2	74.5	106.8	Dwyer	107°50.1'W 32°44.9'N	T18S R10W Sec 13 NW 1/4 NW 1/4 NW 1/4	Mimbres Hot Spring
Gila 5	SW32	62.8	76.3	119.8	Gila National Forest	108°12.5'W 33°12.0'N	T13S R13W Sec 5 NE 1/4 NW 1/4	Gila Hot Spring
Gila 6	SW33	66.3	77.3	120.5	Gila National Forest	108°12.6'W 33°12.0'N	T13S R13W Sec 5 NE 1/4 NW 1/4	Gila Hot Spring
Gila 7	SW34	64.8	74.4	128.9	Gila National Forest	108°14.2'W 33°14.0'N	T12S R14W Sec 24 SE 1/4 SE 1/4	Hot Spring
Gila 8	SW35	43.6	62.2	128.9	Gila National Forest	108°12.7'W 33°9.8'N	T13S R13W Sec 17 SW 1/4 NE 1/4	Hot Springs
Gila 9	SW36	N/A	44.4	110.3	Gila National Forest	108°00.5'W 32°34.6'N	T20S R11W Sec 8 SW 1/4 SW 1/4 SW 1/4	Well
Gila 10	SW37	N/A	48.4	111.2	Gila National Forest	108°00.0'W 32°35.1'N	T20S R11W Sec 8 NW 1/4 SE 1/4 SE 1/4	Well
Gila 11	SW38	N/A	55.0	105.9	Gila National Forest	108°2.5'W 32°33.8'N	T20S R11W Sec 18 SW 1/4 SW 1/4 NE 1/4	Well
LD1	SW132	25.3	141.6	84.0	Lordsburg	108°38.8'W 32°18.9'N	T23S R15W Sec 12 SE 1/4 SW 1/4 NW 1/4	Well
LD2	SW133	33.0	150.6	91.2	Muir Ranch	108°30.7'W 32°13.7'N	T24S R16W Sec 8 SE 1/4 NW 1/4 SW 1/4	Well
LD3	SW134	N/A	61.3	95.3	Muir Ranch	108°33.6'W 32°10.6'N	T24S R17W Sec 35 NE 1/4 SW 1/4	Well
LD4	SW135	N/A	57.6	82.5	Coyote Peak	108°34.5'W 32°3.7'N	T26S R17W Sec 10 NW 1/4 NW 1/4 NW 1/4	Lone Hill Well
LD5	SW136	N/A	94.3	99.1	Playas	108°36.9'W 31°55.8'N	T27S R17W Sec 30 SW 1/4 NE 1/4	Well
LD6	SW137	N/A	35.8	89.5	Pratt (no map)	108°48.5'W 31°57.0'N	T27S R19W Sec 12 SE 1/4 SW 1/4 NE 1/4	Well
LD7	SW138	24.4	21.3	99.5	Pratt (no map)	108°46.5'W 31°48.6'N	T29S R19W Sec 4 SE 1/4 SW 1/4 NE 1/4	Well
LD8	SW139	21.2	18.9	97.2	Pratt (no map)	108°52.5'W 31°50.0'N	T28S R20W Sec 34 NE 1/4 NW 1/4 NW 1/4	Well

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
LD9	SW140	18.7	44.7	99.5	Animas Peak (no map)	108°49.9'W 31°40.2'N	T30S R20W Sec 25 NE 1/4 SE 1/4 NE 1/4	Well
LD10	SW141	N/A	57.6	90.9	Animas Peak (no map)	108°52.2'W 31°35.8'N	T31S R20W Sec 22 NE 1/4 SW 1/4 NE 1/4	Well
LD11	SW142	18.3	69.9	104.0	Cienega Springs	108°51.8'W 31°24.2'N	T33S R20W Sec 27 SW 1/4 NW 1/4 SE 1/4	Well
LD12	SW143	18.0	53.3	86.7	Cienega Springs	108°54.9'W 31°23.2'N	T33S R20W Sec 31 SW 1/4 SE 1/4 SE 1/4	Well
LD13	SW144	17.0	56.2	90.9	Cienega Springs	108°47.9'W 31°20.4'N	T34S R19W Sec 18 SE 1/4	Cienega Springs
Gila 30	SW160	24.0	77.8	100.1	Cliff	108°35.5'W 32°48.6'N	T17S R17W Sec 32 NW 1/4 SW 1/4 SW 1/4	Spring
MFG1	SW161	31.0	34.6	102.7	Alum Mountain	108°15.8'W 33°17.0'N	T11S R14W Sec 35 SW 1/4 SE 1/4 (unsurveyed)	Spring
MFG2	SW162	37.0	19.4	107.2	Alum Mountain	108°16.9'W 33°17.4'N	T11S R14W Sec 35 SW 1/4 NE 1/4 (unsurveyed)	Spring
MFG3	SW163	36.0	31.4	107.5	Alum Mountain	108°16.9'W 33°17.4'N	T11S R14W Sec 34 NE 1/4 SE 1/4 (unsurveyed)	Spring
MFG4	SW164	26.0	22.6	105.4	Alum Mountain	108°15.0'W 33°16.4'N	T12S R14W Sec 1 SW 1/4 SW 1/4 SW 1/4 (unsurveyed)	Spring
W50	SW238	N/A	53.3	67.0	Dona Ana Co.	107°9.8'W 32°12.9'N	T24S R3W Sec 17 SE 1/4 SE 1/4	Well
W51	SW239	N/A	69.1	25.0	Dona Ana Co.	107°12.0'W 32°14.1'N	T24S R4W Sec 12 SE 1/4 NW 1/4	Well
W52	SW230	N/A	84.8	92.8	Dona Ana Co.	107°12.7'W 32°11.6'N	T24S R4W Sec 25 NW 1/4 SW 1/4	Well
W53	SW241	N/A	91.8	67.1	Dona Ana Co.	107°14.7'W 32°9.4'N	T25S R4W Sec 3 SW 1/4 SE 1/4	Well
W54	SW242	N/A	77.7	129.9	Dona Ana Co.	107°14.8'W 32°7.8'N	T25S R4W Sec 15 SW 1/4 SW 1/4	Well
W55	SW243	23.0	142.1	108.0	Dona Ana Co.	107°14.5'W 32°5.3'N	T25S R4W Sec 34 SW 1/4 NE 1/4	Well
W56	SW244	N/A	40.9	73.6	Dona Ana Co.	107°7.0'W 32°10.0'N	T25S R3W Sec 2 NE 1/4 NW 1/4	Well
W57	SW245	22.0	128.8	70.4	Dona Ana Co.	107°10.1'W 32°9.2'N	T25S R3W Sec 8 NE 1/4 NW 1/4	Well
W58	SW246	N/A	162.7	91.1	Dona Ana Co.	107°2.5'W 32°8.5'N	T25S R2W Sec 9 SE 1/4 SE 1/4	Well
W59	SW247	24.0	150.0	97.0	Dona Ana Co.	107°0.3'W 32°11.2'N	T24S R2W Sec 25 SW 1/4 SW 1/4	Well
W60	SW248	24.0	83.4	85.3	Dona Ana Co.	106°53.4'W 32°11.3'N	T24S R1W Sec 25 SE 1/4 NE 1/4	Well
W61	SW249	N/A	71.9	55.7	Dona Ana Co.	106°49.2'W 32°9.5'N	T25S R1E Sec 2 SW 1/4 SW 1/4	Well
W62	SW250	N/A	120.1	70.4	Luna County	107°24.5'W 31°48.0'N	T29S R6W Sec 12 NW 1/4 SE 1/4	Well

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
W63	SW251	N/A	77.8	76.6	Luna County	107°30.1'W 31°48.3'N	T29S R7W Sec 12 NE 1/4 NE 1/4	Well
W64	SW252	N/A	194.2	134.1	Luna County	107°34.3'W 31°47.7'N	T29S R7W Sec 8 SE 1/4 SE 1/4	Well
W65	SW253	N/A	99.0	88.3	Luna County	107°23.2'W 31°58.2'N	T27S R5W Sec 7 SE 1/4 SE 1/4	Well
W66	SW254	N/A	91.2	66.2	Luna County	107°26.9'W 31°53.2'N	T28S R6W Sec 9 SE 1/4 NE 1/4	Well
W67	SW255	22.0	77.5	77.3	Luna County	107°30.1'W 31°48.3'N	T29S R7W Sec 12 NE 1/4 NE 1/4	Well
W68	SW256	26.0	191.8	136.4	Luna County	107°34.3'W 31°47.7'N	T29S R7W Sec 8 SE 1/4 SE 1/4	Well
W69	SW257	30.0	106.6	90.6	Luna County	107°31.2'W 31°50.5'N	T28S R7W Sec 26 SE 1/4 NE 1/4	Well
W70	SW258	22.0	74.2	79.0	Luna County	107°26.9'W 31°53.2'N	T28S R6W Sec 9 SE 1/4 NE 1/4	Well
W71	SW259	21.0	91.6	78.7	Luna County	107°23.1'W 31°56.2'N	T27S R5W Sec 3 NE 1/4 NE 1/4	Well
W73	SW261	20.0	44.0	109.7	Luna County	107°35.2'W 31°54.2'N	T28S R7W Sec 5 NW 1/4 NW 1/4	Well
W74	SW262	21.0	44.0	81.7	Luna County	107°40.1'W 32°13.3'N	T26S R8W Sec 28 NW 1/4 NW 1/4	Well
W75	SW273	22.0	120.4	10.3	Luna County	107°26.1'W 32°13.3'N	T24S R6W Sec 14 SW 1/4 NW 1/4	Well
W76	SW274	21.0	43.6	107.3	Luna County	107°28.8'W 32°13.4'N	T24S R6W Sec 17 NW 1/4 SE 1/4	Well
W77	SW275	N/A	52.4	103.6	Luna County	107°28.9'W 32°11.3'N	T24S R6W Sec 29 SW 1/4 SW 1/4	Well
W78	SW276	21.0	54.4	115.6	Luna County	107°28.0'W 32°8.0'N	T25S R6W Sec 16 SW 1/4 NW 1/4	Well
W79	SW277	21.0	131.9	118.9	Luna County	107°28.7'W 32°6.7'N	T25S R6W Sec 29 NW 1/4 NE 1/4	Well
W80	SW278	23.0	75.2	93.9	Luna County	107°23.3'W 32°5.5'N	T25S R5W Sec 31 NE 1/4 SE 1/4	Well
W81	SW279	20.0	73.6	88.9	Luna County	107°25.0'W 32°2.2'N	T26S R6W Sec 24 NW 1/4 NW 1/4	Well
W82	SW280	19.0	68.3	91.7	Dona Ana County	107°00.2'W 32°34.6'N	T20S R2W Sec 12 SW 1/4 SW 1/4	Well
W83	SW281	N/A	113.3	54.1	Dona Ana County	107°2.6'W 32°30.8'N	T21S R2W Sec 4 NE 1/4 SE 1/4	Well
W84	SW282	N/A	58.9	105.3	Dona Ana County	107°4.8'W 32°31.0'N	T21S R2W Sec 6 NE 1/4 NW 1/4	Well
AN1	SW283	18.0	38.5	109.3	Swallow Fork Peak	108°52.2'W 32°11.7'N	T24S R20W Sec 26 NW 1/4 NE 1/4 NE 1/4	
AN2	SW284	19.0	58.1	54.1	Swallow Fork Peak	108°48.8'W 32°12.2'N	T24S R19W Sec 2 SE 1/4 NE 1/4 NW 1/4	

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
AN3	SW285	16.0	41.0	117.1	Swallow Fork Peak	108°52.8'W 32°10.1'N	T24S R20W Sec 34 SE 1/4 SE 1/4	
AN4	SW286	24.0	94.0	135.8	Swallow Fork Peak	108°50.7'W 32°9.7'N	T25S R20W Sec 1 NE 1/4 SE 1/4 NE 1/4	
AN5	SW287	19.0	60.0	102.3	Swallow Fork Peak	108°50.9'W 32°8.1'N	T25S R20W Sec 13 NE 1/4 NW 1/4 SE 1/4	
AN6	SW288	19.0	52.3	79.4	Table Top Mountain	108°51.2'W 32°7.3'N	T25S R20W Sec 13 SW 1/4 SE 1/4 SE 1/4	
AN7	SW289	20.0	52.2	78.7	Table Top Mountain	108°50.8'W 32°6.3'N	T25S R20W Sec 25 NE 1/4 NE 1/4 SE 1/4	
AN8	SW290	N/A	40.7	84.0	Swallow Fork Peak	108°53.2'W 32°7.7'N	T25S R20W Sec 15 SE 1/4 NW 1/4	
AN9	SW291	18.0	61.2	-20.9	Table Top Mountain	108°52.8'W 32°4.8'N	T25S R20W Sec 34 SE 1/4 SE 1/4	
AN10	SW292	19.0	58.0	89.0	Cotton City	108°53.5'W 32°4.5'N	T26S R20W Sec 4 NW 1/4 SE 1/4	
AN11	SW293	19.0	44.9	96.5	Cotton City	108°54.6'W 32°3.1'N	T20S R20W Sec 5 SW 1/4 SE 1/4	
AN12	SW294	21.0	44.8	97.1	Cotton City	108°54.0'W 32°4.7'N	T26S R20W Sec 5 NE 1/4 NE 1/4 NE 1/4	
AN13	SW295	26.0	63.9	82.3	Table Top Mountain	108°52.7'W 32°3.1'N	T26S R20W Sec 14 NW 1/4 NE 1/4 NW 1/4	
AN14	SW296	20.0	44.6	96.0	Cotton City	108°55.0'W 32°2.7'N	T26S R20W Sec 17 NW 1/4 SW 1/4 SW 1/4	
AN15	SW297	24.0	44.1	79.6	Table Top Mountain	108°51.2'W 32°4.3'N	T26S R20W Sec 14 SW 1/4 SW 1/4 SE 1/4	
AN16	SW298	20.0	48.1	88.4	Cotton City	108°53.3'W 32°3.6'N	T26S R20W Sec 9 NE 1/4 SW 1/4 SE 1/4	
AN17	SW299	22.0	80.3	79.6	Table Top Mountain	108°52.7'W 32°4.8'N	T25S R20W Sec 35 SE 1/4 SE 1/4 SE 1/4	
AN18	SW300	21.0	45.3	89.0	Table Top Mountain	108°52.2'W 32°5.6'N	T25S R20W Sec 26 SE 1/4 SW 1/4 SW 1/4	
AN19	SW301	N/A	29.9	91.8	Swallow Fork Peak	108°46.4'W 32°9.1'N	T25S R19W Sec 11 NW 1/4 NW 1/4	
AN20	SW302	20.0	39.2	101.5	Cotton City	108°53.6'W 32°5.2'N	T25S R20W Sec 34 NW 1/4 SW 1/4 SE 1/4	
AN21	SW303	19.0	48.7	89.0	Cotton City	108°55.3'W 32°7.2'N	T25S R20W Sec 20 NW 1/4 NE 1/4 SW 1/4	
AN22	SW304	19.0	47.6	82.9	Table Top Mountain	108°51.7'W 32°6.3'N	T25S R20W Sec 25 NW 1/4 NW 1/4 SW 1/4	
AN23	SW305	18.0	41.4	88.4	Steins	108°52.7'W 32°9.1'N	T25S R20W Sec 2 SW 1/4 SW 1/4 SW 1/4	
SWAN 306	SW306	34.0	22.7	101.4	Alum Mountain	108°15.0'W 33°16.4'N	T12S R14W Sec 1 SW 1/4 SW 1/4 SW 1/4 (unsurveyed)	Spring
SWAN 307	SW307	32.0	22.7	101.9	Alum Mountain	108°15.0'W 33°16.4'N	T12S R14W Sec 1 SW 1/4 SW 1/4 SW 1/4 (unsurveyed)	Spring

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
SWAN 308	SW308	7.0	29.5	76.8	Alum Mountain	108°15.0'W 33°16.4'N	T12S R14W Sec 1 (unsurveyed)	Middle Fork Gila River
SWAN 309	SW309	N/A	29.7	91.3	Alum Mountain	108°12.1'W 33°10.6'N	T13S R13W Sec 8 SE 1/4 NW 1/4 (unsurveyed)	East Fork Gila River
SWAN 310	SW310	N/A	21.8	72.3	Alum Mountain	108°12.3'W 33°10.8'N	T13S R13W Sec 8 NE 1/4 SW 1/4 (unsurveyed)	West Fork Gila River
NM1	SW381	53.5	138.2	120.0	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM2	SW382	48.0	140.3	120.0	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM3	SW383	34.3	137.9	117.8	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM4	SW384	53.0	139.5	118.9	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM5	SW385	58.5	140.3	121.7	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM6	SW386	35.6	140.6	119.6	Santa Fe Nat'l Forest (East)	105°17.4'W 35°39.2'N	T17N R15E Sec 36 SE 1/4 SE 1/4	Montezuma Hot Spring
NM7	SW387	16.5	60.2	33.0	Santa Fe 1:250,000	105°10.8'W 35°36.9'N	T16N R17E Sec 19 SW 1/4 SE 1/4	Windmill
NM8	SW388	12.9	29.7	53.0	Santa Fe 1:250,000	105°06.5'W 35°35.4'N	T16N R17E Sec 26 NE 1/4 SW 1/4	Windmill
NM9	SW389	14.0	24.4	61.5	Santa Fe 1:250,000	105°00.6'W 35°37.2'N	T16N R18E Sec 15 NE 1/4 NE 1/4	Windmill
NM10	SW390	18.0	45.2	59.5	Santa Fe 1:250,000	104°55.5'W 35°36.3'N	T16N R19E Sec 21 NW 1/4 SE 1/4	Windmill
NM11	SW391	14.3	50.0	50.5	Santa Fe 1:250,000	104°50.2'W 35°36.0'N	T16N R20E Sec 20 SE 1/4 NE 1/4	Windmill
NM12	SW392	14.0	16.2	62.5	Santa Fe 1:250,000	104°46.6'W 35°31.2'N	T15N R21E Sec 20 NW 1/4 NW 1/4	Windmill
NM13	SW393	21.0	82.6	40.8	Santa Fe 1:250,000	104°35.8'W 35°27.8'N	T14N R22E Sec 13 SW 1/4 SE 1/4	Windmill
NM14	SW394	20.5	44.9	48.0	Santa Fe 1:250,000	104°27.0'W 35°20.9'N	T13N R23E Sec 24 NE 1/4 NE 1/4	Windmill
NM15	SW395	27.0	80.5	68.8	Carson National Forest (West)	106°02.7'W 36°22.0'N	T25N R8E Sec 25 SE 1/4 SE 1/4 SW 1/4	Spring
NM16	SW396	29.0	79.5	68.8	Carson National Forest (West)	106°02.7'W 36°22.0'N	T25N R8E Sec 25 SE 1/4 SE 1/4 SW 1/4	Spring
NM17	SW397	27.5	83.3	67.9	Carson National Forest (West)	106°02.7'W 36°22.0'N	T25N R8E Sec 25 SE 1/4 SE 1/4 SW 1/4	Spring
NM18	SW398	25.5	79.8	66.2	Carson National Forest (West)	106°02.5'W 36°18.8'N	T25N R8E Sec 36 NE 1/4 NE 1/4	Spring
NM19	SW399	43.5	157.8	114.5	Carson National Forest (West)	106°03.4'W 36°18.3'N	T24N R8E Sec 24 NW 1/4 NW 1/4	Arsenic Spring Ojo Caliente
NM20	SW400	41.1	158.4	115.2	Carson National Forest (West)	106°03.4'W 36°18.3'N	T24N R8E Sec 24 NW 1/4 NW 1/4	Sodium Sulfate Spring Ojo Caliente

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
NM21	SW401	55.6	160.5	121.0	Carson National Forest (West)	106°03.4'W 36°18.3'N	T24N R84 Sec 24 NW 1/4 NW 1/4	Hot Well Ojo Caliente
NM22	SW402	34.4	91.6	105.9	Carson National Forest (East)	105°36.5'W 36°19.4'N	T24N R13E Sec SW 1/4 SW 1/4 SW 1/4	Ponce de Leon Hot Spring
NM23	SW403	11.5	23.1	75.5	Carson National Forest (East)	105°42.9'W 36°20.7'N	T24N R11E Sec 1 NE 1/4 SE 1/4	Spring
NM24	SW404	18.0	43.1	85.9	Carson National Forest (East)	105°44.0'W 36°19.9'N	T24N R11E Sec 11 NE 1/4 NE 1/4	Spring
NM25	SW405	19.0	76.8	85.9	Carson National Forest (East)	105°44.2'W 36°19.9'N	T24N R11E Sec 11 NE 1/4 SW 1/4	Rio Grande Spring
NM26	SW406	19.7	15.5	49.3	Carson National Forest (East)	105°43.6'W 35°15.0'N	T23N R11E Sec 1 SW 1/4 SW 1/4	"Warm" Spring
NM27	SW407	15.0	45.7	86.5	Carson National Forest (East)	105°41.2'W 36°39.9'N	T28N R12E Sec 17 NW 1/4 SE 1/4	Little Arsenic Spring
NM28	SW408	17.5	43.9	83.4	Carson National Forest (East)	105°41.2'W 36°40.4'N	T28 R12E Sec 18 SE 1/4 NW 1/4	Big Arsenic Spring
NM29	SW409	38.3	89.7	110.1	Carson National Forest (East)	105°43.2'W 36°30.6'N	T26N R11E Sec 12 NW 1/4 NE 1/4	Manby Hot Spring
NM30	SW410	32.8	73.4	110.5	Carson National Forest (East)	105°43.2'W 36°30.6'N	T26N R11E Sec 12 NW 1/4 NE 1/4	Manby Hot Spring
NM31	SW411	40.6	167.7	116.01	Carson National Forest (East)	105°42.9'W 36°31.7'N	T27N R11E Sec 36 SE 1/4 NE 1/4	No Name Spring
NM32	SW412	16.0	37.0	80.8	Carson National Forest (East)	105°42.9'W 36°31.7'N	T27N R11E Sec 36 SE 1/4 NE 1/4	Cold Spring
NM33	SW413	57.2	187.5	111.3	San Juan National Forest	107°00.8'W 37°15.9'N	T35N R2W Sec 13 SW 1/4 SE 1/4	Pagosa Hot Spring
NM34	SW414	N/A	21.7	92.2	San Juan National Forest	106°56.5'W 37°30.6'N	T38N R1W Sec 26 NE 1/4 NW 1/4 NW 1/4	Hot Spring
PV1	SW415	N/A	67.5	63.4	Roswell 1:250,000	104°19.6'W 33°19.1'N	T11S R26E Sec 34 SW 1/4	
PV2	SW416	N/A	19.8	84.6	Roswell 1:250,000	104°16.0'W 33°25.1'N	T10S R25E Sec 26 NW 1/4 SE 1/4	Windmill
PV3	SW417	N/A	-2.1	78.7	Roswell 1:250,000	104°29.9'W 33°15.1'N	T12S R24E Sec 24 SE 1/4 SE 1/4	
PV4	SW418	N/A	1.5	81.4	Roswell 1:250,000	104°30.3'W 33°11.8'N	T13S R24E Sec 13 NW 1/4 NW 1/4	Windmill
PV5	SW419	N/A	-2.3	43.9	Roswell 1:250,000	104°14.7'W 33°13.1'N	T13S R27E Sec 4 SW 1/4 NW 1/4 NW 1/4	Windmill
PV6	SW420	N/A	50.9	53.0	Roswell 1:250,000	104°11.8'W 33°11.1'N	T13S R27E Sec 13 SW 1/4 SW 1/4 SW 1/4	Windmill
PV7	SW421	N/A	16.0	78.0	Roswell 1:250,000	104°8.2'W 33°10.1'N	T13S R28E Sec 28 NW 1/4 NW 1/4 NW 1/4	Windmill
PV8	SW422	N/A	3.3	75.1	Roswell 1:250,000	104°27.8'W 33°4.4'N	T14S R25E Sec 29 NE 1/4 SW 1/4	
PV9	SW423	N/A	9.9	72.8	Roswell 1:250,000	104°30.8'W 33°4.4'N	T14S R24E Sec 26 SE 1/4 NW 1/4 NW 1/4	

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
PV10	SW424	N/A	4.5	71.2	Roswell 1:250,000	104°31.6'W 33°4.1'N	T14S R24E Sec 34 NE 1/4 NE 1/4 NW 1/4	
PV11	SW425	N/A	12.5	61.5	Roswell 1:250,000	104°41.3'W 33°3.1'N	T15S R23E Sec 6 NW 1/4 NE 1/4 NW 1/4	
T1	SW426	N/A	50.8	80.8	Hueco Tanks	106°02.4'W 57°00.0'N		Well
T2	SW427	N/A	64.7	35.9	San Antonio Mountain	105°37.0'W 31°46.2'N		Well
T3	SW428	N/A	74.9	59.5	Van Horn 1:250,000	105°28.1'W 31°46.8'N		Well
T4	SW429	N/A	46.2	87.7	Emory Peak 1:250,000	103°33.0'W 29°44.2'N		Windmill
T5	SW430	N/A	69.7	37.6	Emory Peak 1:250,000	103°24.7'W 29°31.9'N		Windmill
T6	SW431	N/A	27.0	92.2	Emory Peak 1:250,000	103°22.0'W 29°33.2'N		Windmill
T7	SW432	N/A	-15.3	85.3	Emory Peak	103°20.5'W 29°29.4'N		Spring
T8	SW433	N/A	12.6	101.8	Emory Peak	103°20.5'W 29°29.4'N		Spring
T9	SW434	N/A	66.8	94.9	Emory Peak	103°31.4'W 29°19.0'N		Well
T10	SW435	N/A	82.0	17.2	Emory Peak	103°24.0'W 29°32.8'N		Well
T11	SW436	N/A	54.9	95.4	Emory Peak	103°24.0'W 29°32.8'N		Windmill
T12	SW437	N/A	71.6	56.4	Emory Peak	103°29.8'W 29°35.1'N		Well
T13	SW438	N/A	137.3	-6.6	Emory Peak	103°29.9'W 29°32.9'N		Windmill
T14	SW439	N/A	25.7	66.2	Emory Peak	103°10.2'W 20°43.2'N		
T15	SW440	N/A	59.4	58.5	Emory Peak	103°24.9'W 29°46.3'N		Windmill
RM50	SW441	N/A	29.0	36.2	Gallup 1:250,000	108°34.9'W 35°35.2'N	T16N R16W Sec 30 SW 1/4 NE 1/4	Well
RM51	SW442	N/A	75.6	66.2	Gallup 1:250,000	108°34.7'W 35°55.3'N	T19N R18W Sec 21 SW 1/4 NE 1/4	Artesian Well
RM52	SW443	N/A	52.1	46.7	Gallup 1:250,000	108°45.9'W 35°51.7'N	T20N R16W Sec 31 NW 1/4 SW 1/4 SW 1/4	Tohatchi Public School Well
STROM	SW444	N/A	36.6	69.3	Dona Ana Co.	106°43 W 32°19 N	T23S R2E	
RK1	SW445	12.0	3.8	55.3	Lincoln Nat'l Forest	105°40.1'W 33°18.2'N	T12S R13E Sec 3 NW 1/4 NE 1/4 NE 1/4	Spring
RK2	SW446	N/A	1.5	57.4	Lincoln Nat'l Forest	105°39.2'W 33°22.1'N	T11S R13E Sec 14 SW 1/4 NE 1/4 NW 1/4	Bogg Spring
RK3	SW447	N/A	0.7	64.4	Lincoln Nat'l Forest	105°43.5'W 33°22.1'N	T11S R13E Sec 7 SW 1/4 NW 1/4 NW 1/4	Spring

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
RK4	SW448	5.0	4.6	61.3	Lincoln Nat'l Forest	105°44.2'W 33°25.0'N	T10S R12E Sec 25 NW 1/4 NE 1/4 SW 1/4	Spring
RK5	SW449	12.0	10.1	53.0	Lincoln Nat'l Forest	105°40.4'W 33°26.7'N	T10S R13E Sec 15 NW 1/4 SW 1/4 SW 1/4	Well
RK6	SW450	N/A	-20.2	65.3	Lincoln Nat'l Forest	105°38.9'W 33°27.9'N	T10S R13E Sec 2 SE 1/4 SW 1/4 SW 1/4	Windmill
RK7	SW451	N/A	-7.0	74.4	Lincoln Nat'l Forest	105°37.7'W 33°30.9'N	T9S R13E Sec 24 NE 1/4 SW 1/4 NE 1/4	Windmill
RK8	SW452	N/A	4.1	73.6	Lincoln Nat'l Forest	105°39.1'W 33°35.2'N	T8S R13E Sec 26 NW 1/4 SE 1/4 NW 1/4	Windmill
RK9	SW453	N/A	27.6	53.0	Lincoln National Forest	105°40.9'W 33°32.5'N	T9S R13E Sec 9 SE 1/4 NW 1/4 SW 1/4	Spring
RK10	SW454	N/A	10.3	63.4	Lincoln National Forest	105°40.2'W 33°28.0'N	T10S R13E Sec 5 SW 1/4 NE 1/4 SE 1/4	Spring
RK11	SW455	N/A	-9.2	56.4	Lincoln National Forest	105°45.2'W 33°27.2'N	T10S R11E Sec 12 SE 1/4 NE 1/4 SW 1/4	Spring
RK12	SW456	N/A	7.4	58.4	Lincoln National Forest	105°47.5'W 33°29.0'N	T9S R11E Sec 34 SW 1/4 NE 1/4 NE 1/4	Skull Spring
RK13	SW457	N/A	11.7	58.5	Lincoln National Forest	105°39.7' 33°53.6'	T7S R10E Sec 34 NW 1/4 NW 1/4 NE 1/4	Scott Springs
RK14	SW458	14.0	25.5	69.6	Lincoln National Forest	105°36.1' 33°31.8'	T8S R14E Sec 24 NE 1/4 SW 1/4 SW 1/4	Windmill
RK15	SW459	11.0	9.6	82.1	Lincoln National Forest	105°21.7' 33°33.6'	T9S R16E Sec 3 NE 1/4 NW 1/4 NW 1/4	Spring
RK16	SW460	N/A	9.9	66.2	Lincoln National Forest	105°37.3' 33°37.4'	T8S R14E Sec 7 SW 1/4 SW 1/4 SW 1/4	Well
RK17	SW461	N/A	87.7	75.1	Lincoln National Forest	105°35.4' 33°42.6'	T7S R14E Sec 8 SE 1/4 SE 1/4 SW 1/4	Windmill
RK18	SW462	N/A	23.9	12.2	Lincoln National Forest	105°36.0' 33°42.6'	T7S R14E Sec 8 SW 1/4 SE 1/4 SW 1/4	Windmill
RK19	SW463	N/A	1.5	57.4	Lincoln National Forest	105°38.3' 33°44.1'	T7S R13E Sec 1 NW 1/4 NW 1/4 NW 1/4	Spring
RK20	SW464	N/A	19.0	57.4	Lincoln National Forest	105°40.0' 33°47.4'	T6S R13E Sec 15 NE 1/4 SW 1/4 NW 1/4	Well
RK21	SW465	N/A	16.9	79.4	Lincoln National Forest	105°42.5' 33°55.7'	T4S R12E Sec 29 SE 1/4 NW 1/4 SW 1/4	Windmill
RK22	SW466	N/A	31.4	70.4	Lincoln National Forest	105°55.5' 33°48.6'	T6S R10E Sec 4 SW 1/4 SW 1/4 SW 1/4	Windmill
RK23	SW467	N/A	22.2	45.8	Lincoln National Forest	105°44.8' 33°44.8'	T6S R11E Sec 36 NE 1/4 NE 1/4 NE 1/4	Windmill
RK24	SW468	N/A	2.6	46.7	Lincoln National Forest	105°42.8' 33°39.9'	T7S R13E Sec 31 NE 1/4 NE 1/4 NE 1/4	Windmill
RK25	SW469	N/A	5.7	98.0	Lincoln National Forest	105°44.2' 33°37.0'	T8S R12E Sec 13 NW 1/4 SE 1/4 NE 1/4	Windmill
W85	SW539	25.0	49.5	97.5	Luna County	107°38.0'W 31°49.3'N	T29S R8W Sec 2 NE 1/4 NE 1/4 NE 1/4	Well

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
W86	SW540	31.1	168.2	104.5	Luna County	107°46.9'W 31°48.1'N	T29S R9W Sec 8 NE 1/4 SW 1/4 SW 1/4	Well
W87	SW541	25.6	139.0	60.5	Luna County	107°49.0'W 31°48.6'N	T29S R10W Sec 1 SW 1/4 SE 1/4 NE 1/4	Well
W88	SW542	22.8	141.7	90.6	Luna County	107°50.3'W 31°47.5'N	T29S R10W Sec 14 NW 1/4 NE 1/4 NW 1/4	Well
W89	SW543	24.4	73.0	80.1	Luna County	107°52.9'W 31°47.5'N	T29S R10W Sec 17 NE 1/4 NE 1/4 NW 1/4	Well
GG1	SW544	N/A	172.0	58.5	Albuquerque 1:250,000	107°49.1'W 35°07.3'N	T10N R9W Sec 7 SW 1/4 SW 1/4	Spring
GG2	SW545	N/A	86.6	53.0	Albuquerque 1:250,000	107°48.9'W 35°5.9'N	T10N R9W Sec 18 NE 1/4 NE 1/4 SE 1/4	Windmill
GG3	SW545	N/A	90.0	88.3	Albuquerque 1:250,000	107°47.0'W 35°5.2'N	T10N R9W Sec 21 NE 1/4 NE 1/4 NE 1/4	Windmill
GG4	SW547	N/A	24.1	50.5	Albuquerque 1:250,000	107°48.3'W 35°2.4'N	T9N R9W Sec 5 NE 1/4 NW 1/4 NW 1/4	Windmill
GG5	SW548	N/A	17.8	49.3	Socorro 1:250,000	107°49.8'W 34°56.5'N	T8N R9W Sec 7 NW 1/4 NW 1/4	Windmill
SA1	SW549	34.0	99.6	63.4	Otero Co. (North)	106°9.0'W 32°46.8'N	T18S R8E Sec 5 NW 1/4 SW 1/4 NW 1/4	Carton Well
SA2	SW550	13.0	-8.0	39.3	Lincoln National Forest	105°46.6'W 32°57.6'N	T15S R12E Sec 33 SE 1/4 SE 1/4 SE 1/4	Spring
SA3	SW551	11.0	-21.1	43.9	Lincoln National Forest	105°40.9'W 32°53.5'N	T16S R12E Sec 23 SE 1/4 SE 1/4 NW 1/4	Spring
SA4	SW552	7.0	27.7	34.8	Lincoln National Forest	105°41.0'W 32°44.2'N	T17S R12E Sec 15 SE 1/4 SW 1/4 SE 1/4	Spring
SA5	SW553	12.0	-28.2	37.3	Lincoln National Forest	105°34.2'W 32°47.9'N	T17S R13E Sec 26 SW 1/4 NE 1/4 SW 1/4	Spring
SA6	SW554	N/A	-13.4	42.4	Lincoln National Forest	105°42.1'W 32°37.0'N	T18S R15E Sec 31 NW 1/4 SW 1/4 NE 1/4	Spring
SA7	SW555	16.0	-17.7	35.2	Lincoln National Forest	105°21.9'W 32°35.5'N	T720S R15E Sec 12 NW 1/4 NE 1/4 NE 1/4	Well
SA8	SW556	N/A	4.1	56.4	Lincoln National Forest	105°26.3'W 32°32.5'N	T720S R15E Sec 29 SW 1/4 NW 1/4 NW 1/4	Well
SA9	SW557	21.0	32.0	54.1	Otero County (south)	105°42.0'W 32°17.9'N	T23S R12E Sec 14 NW 1/4 NW 1/4 NW 1/4	Well
SA10	SW558	N/A	-4.7	45.3	Otero County (south)	105°26.8'W 32°20.7'N	T22S R15E Sec 32 SW 1/4 NW 1/4 SW 1/4	Well
SA11	SW559	18.0	15.1	46.7	Otero County (south)	105°19.4'W 32°20.5'N	T23S R16E Sec 5 NE 1/4 NE 1/4 NE 1/4	Well
SA12	SW560	N/A	10.7	55.3	Otero County (south)	105°11.9'W 32°11.1'N	T24S R17E Sec 27 SW 1/4 NE 1/4 SW 1/4	Well
SA13	SW561	N/A	-3.1	55.3	Otero County (south)	105°07.9'W 32°11.8'N	T24S R18E Sec 29 NW 1/4 NE 1/4 NW 1/4	Well
SA14	SW562	19.0	5.2	62.5	Otero County (south)	105°05.4'W 32°05.7'N	T25S R18E Sec 27 SE 1/4 SW 1/4 SW 1/4	Well
SA15	SW563	19.5	10.6	70.4	Eddy County (south)	104°25.0'W 32°15.0'N	T24S R25E Sec 5 NE 1/4 NE 1/4 SE 1/4	Spring

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
SA16	SW564	22.0	12.0	65.3	Eddy County (south)	104°32.2'W 32°17.3'N	T23S R24E Sec 19 SE 1/4 NW 1/4 NE 1/4	Windmill
SA17	SW565	19.0	2.4	53.0	Eddy County (south)	104°36.1'W 32°21.4'N	T22S R23E Sec 26 SE 1/4 SE 1/4 SE 1/4	Windmill
SA18	SW566	26.0	-0.5	67.1	Eddy County (south)	104°28.9'W 32°37.6'N	T21S R24E Sec 27 NE 1/4 NE 1/4 NE 1/4	Spring
SA19	SW567	N/A	12.6	56.4	Eddy County (south)	104°28.1'W 32°27.7'N	T21S R24E Sec 23 SE 1/4 SW 1/4 SE 1/4	Well
SA20	SW568	9.0	-23.8	33.0	Lincoln National Forest	105°41.0'W 32°57.8'N	T15S R13E Sec 33 SW 1/4 SE 1/4 SE 1/4	Spring
US98	SW569	N/A	39.6	92.2	Apache National Forest	108°29.1'W 33°55.2'N	T4S R16W Sec 35 NW 1/4 NW 1/4 SE 1/4	Windmill
US99	SW570	18.9	45.1	100.9	Apache National Forest	108°21.5'W 34°02.3'N	T3S R14W Sec 19 NW 1/4 NW 1/4 NW 1/4	Spring
US100	SW571	N/A	50.5	108.0	Apache National Forest	108°21.0'W 34°65.7'N	T2S R15W Sec 36 NE 1/4 NW 1/4 NW 1/4	Well
US101	SW572	15.6	9.1	84.0	Apache National Forest	108°35.8'W 34°09.5'N	T2S R17W Sec 3 SE 1/4 SW 1/4 NE 1/4	Windmill
US102	SW573	N/A	8.0	74.4	Apache National Forest	108°38.1'W 34°13.2'N	T1S R17W Sec 17 NE 1/4 SE 1/4 SE 1/4	Windmill
US90	SW574	17.0	-3.6	79.4	Clifton 1:250,000	108°42.9'W 33°46.9'N	T6S R18W Sec 17 SE 1/4 SE 1/4 SE 1/4	Large Spring
US91	SW575	21.0	50.1	95.9	Clifton 1:250,000	108°28.8'W 33°55.3'N	T4S R16W Sec 35 NW 1/4 NE 1/4 NW 1/4	Windmill
US92	SW576	15.0	7.7	91.1	Clifton 1:250,000	108°13.3'W 33°56.0'N	T4S R13W Sec 29 NW 1/4 SW 1/4	Windmill
US93	SW577	19.0	55.8	91.7	Clifton 1:250,000	108°11.5'W 33°54.3'N	T5S R13W Sec 3 NW 1/4 SW 1/4 SW 1/4	Windmill
US94	SW578	13.0	52.4	91.1	Clifton 1:250,000	108°10.0'W 33°52.3'N	T5S R13W Sec 14 SE 1/4 SW 1/4 NW 1/4	Windmill
US95	SW579	15.0	43.2	99.9	Clifton 1:250,000	108°20.7'W 33°46.9'N	T6S R15W Sec 13 SW 1/4 SW 1/4 SW 1/4	Windmill
US96	SW580	16.0	59.9	67.1	Clifton 1:250,000	108°28.8'W 33°35.8'N	T8S R16W Sec 22 SW 1/4 SW 1/4 SE 1/4	Turkey Spring
US97	SW581	18.5	27.9	75.0	Clifton 1:250,000	108°32.2'W 33°29.4'N	T9S R17W Sec 25 SE 1/4 NE 1/4 NE 1/4	Spring
US98R	SW582	22.8	93.7	116.4	Wilson Mountain	108°52.6'W 33°14.9'N	T12 R20W Sec 23 NW 1/4 SW 1/4	San Francisco Hot Spring
US105	SW583	20.5	56.7	79.4	St. Johns 1:250,000	108°56.1'W 34°12.2'N	T1S R20W Sec 21 SW 1/4	Windmill
US106	SW584	16.0	24.1	92.8	St. Johns 1:250,000	108°32.9'W 34°20.3'N	T1N R16W Sec 6 SE 1/4 NE 1/4 SE 1/4	Well
US107	SW585	26.0	174.0	39.3	St. Johns 1:250,000	108°46.0'W 34°27.3'N	T3N R18W Sec 30 SW 1/4 NW 1/4 SE 1/4	Salt Lake
US108	SW586	12.0	39.9	77.3	St. Johns 1:250,000	108°31.8'W 34°21.6'N	T2N R16W Sec 33 NW 1/4 NW 1/4 NW 1/4	Windmill

Table 1. (continued).

Field #	Lab #	T ₁ °C	T ₂ °C	T ₃ °C	L ₁	L ₂	L ₃	Name
US109	SW587	12.0	-15.6	84.0	Socorro 1:250,000	107°55.9'W 34°14.4'N	T1S R11W Sec 12 SW 1/4 SW 1/4 S/W 1/4	Windmill
US110	SW588	14.0	21.6	40.8	Socorro 1:250,000	107°52.7'W 34°25.7'N	T2N R10W Sec 3 SW 1/4 NE 1/4 NE 1/4	Windmill
NM53	SW589	N/A	99.0	73.6	Cibola National Forest (Giants)	107°40.2'W 35°20.4'N	T13N R8W Sec 21 SE 1/4 NW 1/4 SE 1/4	Bridge Spring
NM54	SW590	N/A	10.4	68.8	Cibola National Forest (Giants)	107°35.9'W 35°16.8'N	T12N R7W Sec 8 SW 1/4 NE 1/4 SE 1/4	San Mateo Spring
NM55	SW591	N/A	16.4	72.0	Cibola National Forest (Giants)	108°63.1'W 35°06.0'N	T10N R12W Sec 13 NE 1/4 NE 1/4 NE 1/4	La Jura Spring
GC100	SW592	N/A	74.7	79.4	Valencia County	107°40.9'W 35°20.3'N	T13N R8W Sec 21 SE 1/4 NE 1/4 NE 1/4	Spring
GC101	SW593	N/A	49.5	55.3	McKinley County	107°46.8'W 35°20.9'N	T13N R9W Sec 22 NW 1/4 NE 1/4 NE 1/4	Well
GC102	SW594	N/A	21.9	65.3	Valencia County	107°36 0'W 35°16.8'N	T12N R7W Sec 8 SW 1/4 NE 1/4 SW 1/4	Spring
US103	SW595	N/A	49.3	78.0	Dona Ana County	106°40.2'W 32°02.7'N	T26S R2E Sec 14 SE 1/4 NE 1/4 NW 1/4	Well
US104	SW596	N/A	48.7	78.9	Dona Ana County	106°40.2'W 32°02.7'N	T26S R2E Sec 14 SE 1/4 NE 1/4 NW 1/4	Well
Leggs	SW597	N/A	115.3	75.9	Dona Ana County	106°45 W 32°13 N	T24S R2E	

Table 2. Major cations and anions for springs and wells in New Mexico and west Texas.

Field #	Lab #	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
						mg/l					
JW-1	N/A	492	8.12	77.8	38.2	8.3	1.6	0	389.3	2.5	48.0
JW-2	N/A	156	9.60	1.2	<.1	62.8	.4	49.2	72.0	.4	19.2
JW-3	N/A	992	7.89	49.7	6.8	207.2	15.6	0	129.4	445.3	57.6
JW-4	N/A	768	7.95	39.3	7.4	215.6	11.3	0	136.7	294.6	44.2
JW-5	N/A	1,280	7.79	54.3	6.9	406.0	18.8	0	107.4	574.3	90.3
JW-6	N/A	160	8.00	16.8	7.3	23.2	2.0	0	131.8	1.1	19.2
JW-7	N/A	164	7.89	13.0	6.9	27.4	2.7	0	140.3	1.4	15.4
P1	N/A	484	8.20	28.0	7.3	68.7	1.9	0	183.1	20.5	79.3
P2	N/A	1,116	7.71	22.0	0.5	333.6	23.5	0	106.8	88.3	497.1
P3	N/A	1,024	8.16	23.2	0.8	318.6	21.1	0	103.7	87.6	480.0
P4	N/A	1,608	7.84	67.3	5.3	493.1	27.8	0	118.9	111.3	893.4
P5	N/A	1,660	8.08	159.3	34.9	231.7	9.0	0	209.3	181.9	956.3
P10	N/A	1,708	8.18	67.9	17.1	366.2	6.3	0	255.0	133.6	939.0
P13	N/A	756	7.90	38.3	2.7	105.5	3.1	0	237.9	16.7	298.7
P14	N/A	668	8.00	47.9	4.4	71.0	2.7	0	209.3	23.0	289.6
P15	N/A	868	8.07	78.6	12.6	152.2	5.9	0	201.4	80.5	484.7
P20	N/A	632	8.02	43.2	4.1	97.0	2.3	0	192.2	21.3	305.0
P22	N/A	600	7.90	49.3	4.4	111.3	2.7	0	192.2	38.6	311.7
P23	N/A	640	8.08	18.6	2.4	120.2	1.6	0	250.2	29.1	308.3
P24	N/A	1,348	7.92	38.5	1.8	321.4	18.0	0	275.8	79.1	768.5
P25	N/A	604	8.35	38.1	5.7	78.8	3.5	0	183.1	8.9	285.8
W-1	N/A	952	7.75	28.8	8.6	225.5	15.2	0	320.9	88.6	280.5
W-2	N/A	1,236	8.25	46.3	16.4	405.8	26.2	14.4	439.3	318.7	222.9
W-3	N/A	720	8.66	10.2	7.2	223.0	10.6	37.2	334.4	82.2	132.6
W-4	N/A	552	8.50	8.2	8.3	180.7	16.8	25.2	335.6	54.2	94.1
W-5	N/A	784	8.00	9.0	7.5	255.4	14.1	0	317.3	77.6	263.2
W-6	N/A	888	7.93	20.0	10.0	286.4	14.1	0	358.8	83.7	293.9
W-7	N/A	604	8.36	3.0	5.8	238.8	0.4	22.8	369.8	41.5	130.6
W-8	N/A	840	7.94	24.8	13.0	238.8	0.8	0	454.0	79.1	146.0
W-9	N/A	604	9.26	21.4	6.3	236.1	8.2	90.0	263.6	95.7	105.7
W-10	N/A	2,600	8.60	264.1	48.2	414.5	22.7	7.2	46.4	314.4	1219.9
W-11	N/A	1,860	7.56	345.7	80.6	64.6	7.0	0	145.2	19.1	1114.3
W-12	N/A	1,392	7.54	322.2	80.0	72.4	7.4	0	119.6	30.1	1085.5
W-13	N/A	1,848	7.49	240.5	113.3	140.2	5.1	0	175.7	90.4	1027.9
W-14	N/A	1,328	7.69	123.8	70.6	176.5	3.9	0	179.4	129.0	624.4
W-15	N/A	1,224	7.81	110.8	50.1	164.8	9.4	0	120.8	25.2	979.8
W-16	N/A	2,480	7.15	472.7	14.7	197.2	9.8	0	52.5	22.0	1498.6
W-17	N/A	1,968	7.94	321.4	49.0	152.4	9.0	0	45.1	20.6	1181.6
W-18	N/A	2,616	7.59	502.8	29.2	144.1	11.7	0	43.9	20.2	1575.4
W-19	N/A	2,120	8.87	155.7	58.3	388.5	22.3	27.6	37.8	229.7	1018.2
W-20	N/A	372	8.35	36.9	17.9	32.2	5.5	1.2	197.7	20.9	44.2
W-21	N/A	548	7.85	36.9	30.4	65.0	4.7	0	328.3	31.5	61.5
W-22	N/A	364	7.57	43.9	19.8	33.8	4.7	0	225.8	19.8	48.0
W-23	N/A	344	8.21	40.3	18.3	52.9	0.8	0	248.9	23.7	63.4
W-24	N/A	616	8.75	5.6	1.6	265.1	4.3	13.2	428.3	50.7	50.0
W-25	N/A	348	8.59	8.4	4.2	120.0	17.6	0	299.0	14.2	50.0
W-26	N/A	728	9.02	2.6	1.1	271.0	5.5	42.0	454.0	42.9	126.8
W-27	N/A	500	8.50	8.4	8.0	170.6	16.4	13.2	333.2	46.4	80.7
W-28	N/A	768	8.44	24.4	8.6	232.0	12.1	0	222.7	178.0	178.7
W-29	N/A	228	7.48	48.9	7.8	18.6	1.2	0	109.8	3.2	96.1
W-30	N/A	1,436	7.83	270.0	39.8	71.0	3.9	0	158.6	80.1	739.7
W-31	N/A	616	8.95	15.8	6.1	211.7	5.5	21.6	234.3	70.9	186.4
W-32	N/A	720	8.53	19.2	6.3	242.1	7.8	0	379.5	67.0	194.0
W-33	N/A	720	9.42	10.0	2.1	233.3	16.8	69.6	371.0	29.4	101.8
W-34	N/A	604	10.56	3.6	2.3	190.1	20.3	199.2	41.5	23.7	71.1
W-35	N/A	556	8.66	9.6	5.5	196.8	14.1	13.2	458.9	22.3	59.6
W-36	N/A	2,028	8.09	84.5	27.5	671.3	37.9	54.0	445.4	606.9	475.5
B1	N/A	592	8.18	101.2	27.6	65.1	7.4	12.0	361.2	26.6	147.9
B2	N/A	3,532	8.16	118.6	15.2	1135.9	167.0	13.2	378.3	1593.6	263.2
B3	N/A	872	8.26	87.0	14.1	189.0	14.1	0	203.8	227.3	159.5
B4	N/A	2,236	7.66	404.2	29.9	214.0	11.7	0	41.5	14.2	1604.2
B5	N/A	1,240	8.23	47.1	15.8	323.9	18.8	0	366.1	151.0	376.6
B6	N/A	1,228	8.62	47.1	16.0	340.0	19.2	22.8	311.2	153.2	374.6
B7	N/A	252	8.18	39.5	10.5	34.3	4.7	0	185.5	.4	63.4
B8	N/A	2,784	8.03	153.9	17.9	806.7	10.6	0	289.2	828.5	647.5
B9	N/A	2,608	7.79	143.9	18.0	817.5	61.4	0	164.7	1285.2	196.0
B10	N/A	2,688	7.80	143.9	17.9	791.5	63.0	0	162.3	1353.6	169.1
B11	N/A	2,640	7.88	136.5	17.1	764.6	62.6	0	136.7	1370.3	115.3
B12	N/A	1,392	7.90	110.4	9.5	387.4	21.5	0	211.1	602.7	138.3

Table 2. (continued).

Field #	Lab #	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
B13	N/A	294	8.48	17.2	4.3	56.1	3.1	0	162.3	10.3	50.0
B14	N/A	348	8.33	16.4	4.3	68.5	3.1	0	181.8	12.1	69.2
B15	N/A	420	8.14	49.5	4.5	78.4	3.9	0	175.7	80.5	67.2
B16	N/A	352	7.79	53.3	7.1	25.7	2.7	0	146.4	15.6	76.8
B17	N/A	468	8.24	34.9	1.3	125.5	5.1	0	131.8	104.2	96.1
B18	N/A	544	7.91	42.3	1.7	143.5	6.6	0	137.9	132.2	107.6
B19	N/A	2,708	7.98	164.1	18.7	785.6	62.6	0	224.5	1314.2	107.0
B20	SW19	744	8.05	47.0	36.0	149.7	9.7	0	154.9	101.8	299.5
B21	SW20	2,652	8.18	65.8	44.1	706.5	10.5	0	181.8	269.4	1372.8
B22	SW21	5,208	7.99	599.2	273.1	363.1	37.8	0	143.9	232.2	3129.6
B23	SW22	2,152	7.90	420.2	97.5	51.5	4.7	0	134.2	27.7	1296.0
B24	SW23	2,500	8.10	441.2	156.6	66.0	7.0	0	184.2	47.5	1478.4
B25	SW24	516	8.10	44.2	1.7	137.7	5.5	0	124.4	150.1	107.5
B26	SW25	104	7.90	12.8	2.4	10.5	1.6	0	36.6	0.1	44.2
B27	SW26	104	7.81	12.8	2.2	10.8	1.6	0	31.7	0.7	40.3
B28	SW27	192	7.84	23.4	1.7	24.1	0.8	0	108.5	1.4	26.4
G11a 1	28	364	8.10	46.8	7.9	17.4	3.9	0	207.4	1.1	21.6
G11a 2	29	492	7.74	35.6	7.6	90.8	8.2	0	283.0	14.2	72.0
G11a 3	30	456	7.63	25.8	9.6	90.8	2.3	0	256.2	20.8	64.2
G11a 4	31	320	8.97	2.4	<.006	91.7	1.2	20.4	67.1	14.5	84.0
G11a 5	32	408	8.19	10.6	0.1	123.0	3.1	0	108.6	99.4	69.6
G11a 6	33	416	8.15	10.4	0.2	129.7	3.1	0	115.9	100.1	67.2
G11a 7	34	548	7.92	15.4	0.1	151.5	3.5	0	131.1	104.3	118.0
G11a 8	35	516	8.08	18.4	0.8	141.9	2.7	0	125.0	115.7	93.6
G11a 9	36	320	8.15	31.6	13.0	28.9	3.5	0	227.5	1.4	24.0
G11a 10	37	344	7.84	32.0	18.1	24.8	4.3	0	213.5	17.0	16.2
G11a 11	38	428	7.82	39.8	13.2	47.1	5.1	0	236.6	8.5	50.4
LD1	132	564	8.09	7.6	1.4	143.2	5.9	0	234.3	27.6	93.7
LD2	133	816	7.86	28.0	2.7	216.1	11.7	0	314.8	47.5	223.8
LD3	134	740	7.48	117.4	18.7	98.6	10.2	0	218.4	116.6	181.5
LD4	135	592	7.94	10.2	1.8	159.3	1.5	0	301.4	33.0	104.2
LD5	136	796	7.82	15.6	1.3	234.5	5.5	0	400.3	50.7	154.6
LD6	137	208	7.92	22.0	7.3	27.6	2.0	0	147.7	3.5	19.2
LD7	138	208	7.82	40.3	4.9	15.2	2.0	0	156.2	2.5	4.3
LD8	139	184	7.57	26.0	2.2	21.1	1.2	0	109.8	2.8	4.3
LD9	140	176	7.39	21.0	3.2	6.2	4.5	0	65.9	0.7	33.6
LD10	141	156	7.31	17.8	3.3	6.9	6.2	0	57.3	1.4	40.3
LD11	142	200	7.74	16.6	4.8	36.8	5.1	0	173.3	1.4	3.8
LD12	143	136	6.88	15.8	2.9	13.8	3.5	0	37.8	0.7	52.8
LD13	144	132	7.00	8.2	1.7	15.2	2.7	0	22.0	1.4	40.3
LD14	145	160	8.80	2.4	0.5	54.7	0.4	0	137.9	4.2	16.3
LD15	146	212	8.11	27.6	3.2	16.3	3.1	0	124.4	1.0	13.4
LD16	147	164	7.94	29.4	1.7	11.5	2.3	0	117.1	0.1	5.7
LD17	148	168	8.06	21.2	0.7	12.9	1.5	0	98.8	0.1	9.1
LD18	149	320	8.15	18.4	0.6	65.3	1.2	0	173.3	4.2	35.2
G11a 20	150	236	8.66	6.8	1.6	61.1	1.5	0	94.0	4.2	64.8
G11a 21	151	200	8.33	10.6	3.5	48.7	2.0	0	103.7	3.9	43.7
G11a 22	152	260	9.10	2.8	<0.1	69.2	1.2	20.4	40.3	5.0	75.9
G11a 23	153	292	8.53	10.4	0.6	77.9	1.5	0	75.7	25.9	99.4
G11a 24	154	332	8.13	18.4	1.3	92.4	1.5	0	234.3	6.4	49.0
G11a 25	155	400	8.04	8.2	0.8	118.4	2.0	0	244.1	13.1	55.2
G11a 26	156	444	7.64	36.1	6.9	79.3	1.2	0	290.4	10.6	45.1
G11a 27	157	472	8.79	2.4	0.1	146.7	0.8	13.2	175.7	33.0	107.1
G11a 28	158	272	9.36	1.0	<0.1	87.6	0.4	46.8	125.7	2.8	13.4
G11a 29	159	544	8.00	87.0	16.5	34.9	7.8	0	390.5	18.8	35.0
G11a 30	160	672	7.98	10.0	1.3	190.6	2.7	0	336.8	18.8	142.6
MFC1	161	196	8.08	20.4	2.6	40.0	1.6	0	145.8	3.2	29.8
MFC2	162	188	8.07								
MFC3	163	192	8.09	16.8	1.6	43.7	1.2	0	139.7	3.9	28.3
MFC4	164	168	8.15	14.8	1.5	37.5	.8	0	131.2	3.2	19.2
W-50	238	532	7.88	18.8	16.5	144.6	2.0	0	185.5	67.7	156.0
W-51	239	692	8.77	7.4	3.9	220.2	1.6	49.5	323.4	39.3	83.1
W-52	240	880	8.51	8.0	6.2	230.3	2.7	0	444.2	40.1	111.4
W-53	241	960	8.88	11.6	8.7	293.8	3.9	48.3	231.2	122.3	220.9
W-54	242	1,092	7.98	0.4	0.1	333.3	1.2	0	510.1	61.0	192.6
W-55	243	912	8.11	1.8	1.1	261.6	7.0	0	403.3	74.0	164.3
W-56	244	492	8.35	25.2	13.4	128.0	1.6	0	177.0	57.8	137.8
W-57	245	1,344	8.03	17.8	13.4	432.7	10.6	0	371.6	161.7	450.0
W-58	246	956	7.77	19.2	8.5	302.1	17.6	0	512.5	89.3	245.4

Table 2. (continued).

Field	Lab	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
						mg/l					
W-59	247	864	7.99	8.2	2.7	269.2	10.9	0	317.9	80.1	247.3
W-60	248	432	7.91	25.2	4.5	115.2	7.0	0	161.7	54.2	111.4
W-61	249	620	7.44	48.1	14.1	144.6	7.0	0	142.8	125.5	172.9
W-62	250	2,840	7.95	31.3	15.7	855.7	14.9	0	522.9	449.9	847.2
W-63	251	2,896	8.34	24.4	6.2	922.8	4.7	0	341.1	122.3	1491.8
W-64	252	2,832	7.91	58.1	22.1	908.8	79.4	0	1598.0	368.0	450.0
W-65	253	843	7.95	30.5	18.5	233.8	9.8	0	232.5	269.4	91.7
W-66	254	2,600	8.38	8.6	3.2	1023.5	6.3	46.2	585.1	589.6	794.4
W-67	255	2,740	8.29	20.2	5.5	859.6	4.3	0	327.0	112.4	1367.4
W-68	256	2,748	7.36	65.2	19.8	881.0	75.4	0	1565.7	338.9	423.6
W-69	257	1,168	8.70	1.4	0.2	416.1	3.9	25.5	367.3	234.7	236.8
W-70	258	2,520	8.35	9.0	2.9	900.7	3.5	0	657.8	512.6	635.4
W-71	259	736	8.52	4.2	2.4	265.3	2.3	24.3	245.3	193.9	67.2
W-72	260	808	8.06	29.8	16.9	227.4	9.4	0	208.7	275.8	79.2
W-73	261	516	8.39	14.2	3.4	137.7	1.2	0	270.9	31.9	60.0
W-74	262	328	8.61	32.3	16.6	41.6	3.1	0	197.1	12.0	54.7
W-75	273	340	8.74	1.2	0.1	115.9	2.3	32.4	140.9	23.4	46.6
W-76	274	380	8.13	12.4	4.5	100.5	1.2	0	225.1	20.9	49.5
W-77	275	676	8.31	11.2	4.2	216.3	1.2	0	317.9	49.3	169.5
W-78	276	904	8.12	23.4	10.2	252.6	2.0	0	361.8	75.5	229.6
W-79	277	1,152	7.98	19.0	6.6	381.4	10.6	0	460.7	96.8	339.1
W-80	278	608	8.29	9.0	3.0	195.2	2.3	0	311.8	84.4	70.6
W-81	279	832	7.86	15.2	7.0	297.2	2.7	0	326.4	210.6	91.3
W-82	280	3,020	7.48	166.7	50.8	762.6	8.2	0	276.4	882.8	588.4
W-83	281	6,764	7.60	253.7	126.9	1766.8	28.9	0	200.7	796.7	1677.7
W-84	282	575	7.96	18.4	8.4	164.4	2.3	0	411.9	14.5	50.0
AN 1	283	300	7.88	26.2	2.2	54.0	2.0	0	151.3	7.1	42.0
AN 2	284	360	8.00	13.0	1.6	115.4	2.0	0	241.0	23.7	44.0
AN 3	285	380	8.29	39.7	3.8	66.9	2.7	0	207.4	15.6	64.8
AN 4	286	1,372	7.59	79.7	8.3	353.3	14.1	0	228.8	122.7	492.8
AN 5	287	1,184	7.82	22.0	25.3	178.6	8.2	0	172.1	144.3	351.9
AN 6	288	1,020	8.00	25.2	14.6	161.4	6.6	0	83.6	117.0	369.0
AN 7	289	624	7.52	60.5	9.7	134.3	4.3	0	195.2	68.1	167.0
AN 8	290	272	7.83	28.8	2.7	55.6	2.3	0	170.8	3.5	51.6
AN 9	291	384	7.85	19.8	4.7	98.2	3.1	0	81.1	59.2	107.3
AN 10	292	524	7.92	29.8	8.5	112.2	3.5	0	156.8	53.9	111.7
AN 11	293	688	7.68	81.8	9.1	110.6	4.3	0	202.0	38.3	198.6
AN 12	294	384	7.73	34.5	3.0	77.9	2.7	0	185.5	8.5	74.8
AN 13	295	420	8.26	25.0	1.8	103.4	3.9	0	167.8	27.3	84.0
AN 14	296	340	7.75	26.0	1.8	70.3	2.3	0	176.3	1.8	58.8
AN 15	297	240	7.93	18.2	2.5	49.6	2.0	0	139.1	6.4	38.4
AN 16	298	384	8.39	30.7	3.0	89.9	2.7	0	178.8	19.8	86.9
AN 17	299	524	8.17	30.7	5.7	129.2	7.0	0	237.4	29.4	113.3
AN 18	300	352	8.43	31.3	3.2	67.8	2.7	0	157.4	27.3	58.8
AN 19	301	675	8.33	81.0	23.5	74.5	2.7	0	181.8	42.5	197.0
AN 20	302	628	7.41	76.1	7.2	91.7	3.5	0	187.9	64.2	124.9
AN 21	303	404	8.27	39.9	6.3	74.5	3.5	0	186.7	9.6	88.5
AN 22	304	396	8.41	25.4	2.5	93.8	2.3	0	172.1	20.9	76.0
AN 23	305	284	8.44	22.0	2.1	53.4	2.0	0	148.0	2.1	51.8
N/A	306	192	8.12	14.2	1.3	35.2	0.8	0	82.0	1.4	44.0
N/A	307	224	8.44	14.0	1.3	34.0	0.8	0	97.6	1.1	23.0
N/A	308	116	7.89	9.0	2.3	9.9	1.2	0	54.3	0.4	11.6
N/A	309	240	8.45	24.4	4.2	31.5	1.6	0	109.8	18.8	26.4
N/A	310	76	8.02	12.4	2.4	7.1	1.2	0	51.2	0.4	8.8
NM1	381	432	9.09	4.8	0.1	180.5	5.9	153.1	21.6	69.5	80.7
NM2	382	452	9.10	3.6	0.1	180.5	5.9	151.0	19.2	72.0	79.7
NM3	383	464	8.16	5.8	0.2	173.8	5.9	148.9	0	120.8	80.7
NM4	384	460	9.01	3.6	0.1	185.3	5.9	152.1	18.0	78.1	80.7
NM5	385	448	9.03	3.2	0.1	186.2	5.9	153.9	20.4	73.2	78.8
NM6	386	400	9.10	3.2	0.1	184.1	5.9	151.0	20.4	73.2	81.6
NM7	387	1,084	7.97	4.0	1.2	440.7	1.2	29.8	0	145.9	23.0
NM8	388	2,772	6.56	264.7	208.2	91.0	5.5	25.9	0	108.6	1383.3
NM9	389	536	7.72	84.0	18.7	39.8	2.7	59.6	0	245.3	76.8
NM10	390	484	8.08	71.7	35.2	34.0	5.9	40.1	0	312.4	72.0
NM11	391	388	7.74	66.9	28.6	50.0	5.9	25.9	0	313.6	78.8
NM12	392	296	7.75	80.2	7.4	19.8	2.3	30.1	0	235.5	41.3
NM13	393	946	8.32	23.4	15.5	305.1	4.7	27.3	9.6	640.7	205.6
NM14	394	416	7.90	41.7	20.7	95.2	2.7	21.6	0	319.7	109.5
NM15	395	1,124	6.51	137.7	55.3	191.0	16.8	107.8	0	696.8	238.2

Table 2. (continued).

Field #	Lab #	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
						mg/l					
NH16	396	1,080	6.50	141.9	57.4	185.3	16.8	107.8	0	705.4	234.4
NH17	397	1,226	6.50	119.8	49.1	186.2	16.8	108.5	0	699.2	238.2
NH18	398	1,072	6.62	138.9	56.5	183.2	16.8	107.4	0	695.6	219.0
NH19	399	2,652	7.03	21.6	7.6	993.1	36.0	235.4	0	2172.2	187.3
NH20	400	2,668	7.20	20.2	7.4	993.1	36.0	237.2	0	2245.4	187.3
NH21	401	2,576	7.74	11.6	4.8	1,017.7	34.8	251.7	0	2123.4	196.9
NH22	402	512	8.56	10.0	0.6	160.2	4.3	89.0	0	112.3	144.1
NH23	403	272	7.90	43.9	8.1	22.7	1.9	11.3	0	150.1	49.0
NH24	404	284	8.31	38.7	5.8	37.5	3.5	0.3	0	152.5	66.3
NH25	405	356	8.35	14.8	1.4	94.2	4.3	0	0	283.1	25.0
NH26	406	56	7.17	5.2	1.5	1.8	0.8	0	0	28.1	3.8
NH27	407	184	8.10	16.8	4.8	20.5	2.7	0.7	0	108.6	20.2
NH28	408	112	8.14	18.8	5.2	21.1	2.7	2.5	0	109.8	21.2
NH29	409	552	7.36	27.4	5.1	128.0	8.6	52.1	0	217.2	121.0
NH30	410	396	7.43	28.8	5.5	72.4	6.6	24.8	0	192.8	60.5
NH31	411	584	8.14	22.8	5.2	149.2	12.5	57.1	0	196.5	137.4
NH32	412	232	8.25	32.5	7.8	12.9	3.5	0	0	133.0	31.7
NH33	413	3,164	7.00	154.3	25.5	805.6	76.6	176.9	0	876.2	1330.4
NH34	414	216	9.23	2.2	0.1	47.3	0.2	0	16.8	61.0	30.7
PV 1	415	11,352	7.89	923.8	175.0	2,366.7	17.2	0	186.7	3843.4	224.78
PV 2	416	3,652	8.27	529.0	138.3	71.7	6.2	0	135.4	79.1	1690.7
PV 3	417	836	7.90	116.4	42.8	20.9	1.2	0	157.4	14.2	338.1
PV 4	418	944	7.88	124.4	45.3	21.1	1.5	0	205.1	12.8	338.1
PV 5	419	3,384	7.97	527.8	86.1	36.3	2.7	0	131.6	90.0	1436.1
PV 6	420	4,696	7.41	487.2	322.7	215.9	14.1	0	209.9	159.5	2391.9
PV 7	421	3,960	8.04	524.6	206.4	75.8	5.1	0	130.6	15.2	2017.3
PV 8	422	936	7.30	127.8	41.9	29.2	1.5	0	236.7	13.8	318.9
PV 9	423	640	8.56	96.2	31.2	18.1	2.0	14.4	186.7	7.4	211.3
PV10	424	704	8.49	97.0	31.0	20.0	1.5	13.2	166.0	10.3	228.6
PV11	425	812	8.39	86.6	54.4	21.1	2.0	7.2	172.1	16.7	322.8
T 1	426	288	7.67	80.2	8.4	23.5	10.56	0	283.1	8.5	48.0
T 2	427	1,568	7.53	149.1	83.0	430.6	8.21	0	403.9	296.4	803.1
T 3	428	1,616	7.73	141.7	62.1	358.4	11.7	0	314.8	302.4	674.4
T 4	429	448	8.35	39.7	1.6	173.1	2.35	0	461.3	18.1	72.1
T 5	430	1,316	8.58	31.7	7.8	407.4	3.5	13.2	402.7	57.8	482.2
T 6	431	2,836	7.46	264.7	70.8	554.3	2.74	0	441.8	209.2	2160.4
T 7	432	208	8.18	68.1	2.6	22.3	0.39	0	177.0	4.6	214.7
T 8	433	632	8.21	90.2	13.4	108.5	1.17	0	357.6	19.5	527.9
T 9	434	5,208	7.01	439.5	112.7	1080.5	13.3	0	803.0	30.8	2977.9
T10	435	12,012	8.03	99.8	111.6	3490.8	16.4	0	235.5	128.7	7367.9
T11	436	1,096	7.98	41.1	13.9	335.9	2.74	0	441.8	39.7	903.0
T12	437	3,656	8.09	269.3	100.9	775.9	12.5	0	713.9	292.5	1705.1
T13	438	2,616	9.22	5.0	28.6	1011.8	18.4	82.8	297.8	449.9	1335.3
T14	439	244	8.07	56.3	15.80	14.0	3.13	0	249.0	1.8	219.5
T15	440	660	7.87	106.6	55.67	36.1	12.51	0	488.1	2.8	561.0
NH50	441	252	7.70	34.5	5.6	58.2	1.6	0	200.1	13.8	56.7
NH51	442	376	8.92	1.2	.01	152.4	0.8	12.0	181.8	2.5	142.2
NH52	443	212	8.10	35.1	19.1	17.5	5.9	0	194.5	1.4	40.3
STROM	444	768	1.74	74.1	11.5	46.4	3.9	0	0	62.4	32.7
RF 1	445	1,136	7.22	164.7	48.6	42.8	1.6	0	61.0	47.5	390.0
RF 2	446	1,900	7.54	299.4	61.1	100.9	1.6	0	453.7	113.8	653.7
RF 3	447	520	7.55	101.2	17.4	24.1	1.2	0	260.0	19.8	150.0
RF 4	448	332	7.71	23.6	3.9	63.4	0.4	0	128.1	15.6	56.5
RF 5	449	1,584	6.96	255.5	47.4	86.9	2.3	0	378.3	163.8	436.6
RF 6	450	1,716	7.32	264.3	53.7	144.4	0.4	0	323.4	131.9	713.7
RF 7	451	1,632	7.56	232.8	43.5	128.7	0.8	0	246.5	108.1	631.1
RF 8	452	1,832	7.58	250.0	53.9	162.8	1.6	0	244.1	216.3	552.8
RF 9	453	552	7.83	101.8	17.5	40.2	3.5	0	225.8	26.2	181.5
KK10	454	796	7.77	141.3	26.5	41.2	2.0	0	280.7	37.9	265.1
KK11	455	144	7.33	23.6	4.7	7.4	0.4	0	28.1	2.1	62.9
KK12	456	548	7.49	95.8	20.0	24.6	1.6	0	166.0	18.1	199.3
KK13	457	3,475	7.71	485.2	167.8	390.4	2.3	0	205.0	745.9	1377.0
KK14	458	1,472	7.79	220.2	34.3	104.6	3.9	0	324.6	95.7	470.2
KK15	459	116	7.19	18.4	3.0	9.9	0.8	0	33.0	3.2	46.1
KK16	460	1,580	7.32	254.7	39.9	83.4	2.3	0	346.6	113.8	490.9
KK17	461	876	8.99	4.6	11.1	306.9	2.3	39.6	163.5	149.6	288.7
KK18	462	1,316	7.85	161.5	40.0	139.1	2.7	0	177.0	147.5	466.4
KK19	463	700	7.15	116.2	22.8	36.8	1.2	0	240.4	53.2	176.3
PP20	464	2,464	6.88	414.8	137.8	118.7	0.0	0	525.7	222.0	810.7

Table 2. (continued).

Field #	Lab #	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
						mg/l					
KK21	465	980	7.60	126.6	39.6	83.4	2.0	0	228.2	103.9	282.9
KK22	466	1,728	7.64	172.1	53.8	184.1	3.5	0	101.3	95.4	782.9
KK23	467	1,920	7.61	240.5	81.4	112.9	3.5	0	273.4	220.9	597.5
KK24	468	1,128	7.74	205.2	31.7	56.8	1.6	0	272.1	124.4	320.4
KK25	469	1,996	7.73	238.5	75.5	119.5	1.6	0	878.0	194.3	691.2
W85	539	752	8.21	9.8	3.9	259.3	9.8	0	372.2	61.3	205.6
W86	540	732	7.82	26.4	4.2	244.6	18.0	0	346.6	52.8	245.9
W87	541	560	8.54	10.0	17.7	172.9	6.6	0	263.6	53.9	171.0
W88	542	516	8.61	6.4	5.8	192.6	7.0	20.4	256.3	46.4	141.2
W89	543	388	8.15	17.2	3.0	119.5	3.9	9.6	201.4	36.9	90.3
GG1	544	7,552	8.40	150.7	414.3	1481.9	86.0	28.8	438.1	1111.4	3535.1
GG2	545	2,348	7.44	156.1	111.7	423.5	16.8	0	504.0	319.4	922.2
GG3	546	888	9.18	35.3	65.6	166.2	9.4	28.8	86.6	123.0	426.5
GG4	547	312	7.86	46.1	21.4	28.5	2.0	0	208.7	7.8	13.6
GG5	548	392	7.49	103.0	20.3	25.3	2.7	0	385.6	2.5	78.8
SA1	549	9,140	7.12	645.3	186.0	2030.4	37.1	0	130.6	2476.7	2588.7
SA2	550	536	7.51	108.2	25.9	23.7	0.8	0	368.5	73.4	110.5
SA3	551	280	7.70	85.6	17.5	12.9	0.4	0	301.4	4.2	53.8
SA4	552	284	7.60	86.2	12.0	4.8	6.4	0	308.7	1.8	8.6
SA5	553	360	7.54	107.4	12.9	5.5	0.4	0	372.2	1.4	20.2
SA6	554	396	7.47	108.2	22.8	9.8	0.8	0	428.3	1.8	14.4
SA7	555	352	7.35	99.2	21.5	3.9	0.8	0	402.7	0.7	7.7
SA8	556	304	7.83	60.3	25.0	14.2	1.2	0	225.8	10.6	73.0
SA9	557	1,032	7.16	163.5	68.7	74.0	4.7	0	399.0	28.0	489.9
SA10	558	420	7.56	94.6	32.2	9.2	1.2	0	272.1	3.2	163.3
SA11	559	304	7.79	47.9	23.1	43.2	1.2	0	253.8	11.3	69.2
SA12	560	2,036	7.29	302.8	101.5	81.6	2.7	0	201.4	44.3	1,071.1
SA13	561	1,060	7.21	168.7	59.3	13.1	1.7	0	285.6	4.2	441.1
SA14	562	4,164	7.31	567.7	239.5	131.0	2.7	0	205.0	115.6	2,219.0
SA15	563	612	7.53	81.0	48.4	23.0	1.7	0	300.2	16.0	180.6
SA16	564	700	7.72	97.6	46.5	25.3	2.0	0	228.2	8.1	303.5
SA17	565	504	7.29	89.2	46.8	9.2	1.7	0	323.4	3.2	182.5
SA18	566	1,020	7.44	181.0	65.4	13.8	2.0	0	312.4	8.5	474.5
SA19	567	2,124	7.20	305.8	122.5	16.1	5.1	0	296.5	4.2	1,012.5
SA20	568	408	7.53	96.2	14.9	9.9	0.4	0	356.3	4.2	17.3
JS98	569	124	8.01	18.0	5.3	19.1	2.3	0	129.3	1.4	4.8
JS99	570	116	7.45	19.6	6.3	8.7	3.9	0	101.3	1.4	17.3
SI00	571	184	7.61	32.5	10.2	15.4	5.5	0	185.5	0.7	3.8
SI01	572	480	7.82	27.0	12.1	158.6	0.4	0	477.1	22.3	10.9
SI02	573	804	7.66	38.3	23.0	273.4	0.4	0	641.9	97.5	13.2
US90	574	172	7.54	62.5	10.4	16.1	0.8	0	266.0	1.1	5.8
US91	575	76	9.05	13.2	4.9	20.7	2.7	14.4	91.5	2.5	4.8
US92	576	228	7.83	18.0	3.6	58.2	0.4	0	195.2	10.6	10.6
US93	577	292	8.87	12.6	4.4	85.1	2.0	18.0	200.1	21.3	11.5
US94	578	336	8.62	1.8	0.5	150.3	0.4	16.8	289.2	31.5	14.0
US95	579	220	7.92	20.0	9.2	7.3	3.9	0	119.6	1.1	7.7
US96	580	92	6.69	9.0	3.6	3.2	5.5	0	37.8	1.4	15.4
US97	581	164	7.45	20.8	8.3	6.2	2.3	0	100.1	1.4	14.4
US98	582	596	7.76	36.1	6.2	172.4	10.5	0	139.1	236.8	14.6
SI05	583	232	8.15	23.2	16.5	42.8	3.9	0	255.0	9.2	7.7
SI06	584	572	7.77	80.1	21.9	100.7	1.9	0	383.2	118.0	13.4
SI07	585	220,152	8.24	195.2	4,884.9	66,204.9	1173.0	0	238.0	100,937.9	28,722.4
SI08	586	716	8.21	12.8	8.3	235.9	0.8	0	589.4	44.0	40.3
SI09	587	486	7.46	96.2	22.4	42.3	0.4	0	377.1	15.6	97.0
SI10	588	516	7.92	32.3	8.9	156.8	0.8	0	361.2	38.1	149.8
RM53	589	892	8.08	31.3	46.9	247.8	9.8	21.6	864.0	23.4	80.7
RM54	590	40	7.17	10.6	2.3	3.7	0.8	0	37.8	5.0	5.8
RM55	591	220	7.11	54.1	8.5	14.2	2.0	0	239.2	1.8	5.8
GI00	592	572	7.51	37.3	17.9	156.3	6.3	0	574.8	16.3	8.6
GI01	593	624	8.13	45.7	8.5	151.6	3.1	0	263.6	13.5	207.0
GI02	594	56	6.75	9.4	2.3	4.1	1.2	0	41.5	1.4	5.8
JN-1	N/A	492	8.12	77.8	38.2	8.3	1.6	0	389.3	2.5	48.0
JN-2	N/A	156	9.60	1.2	<1	62.8	4	49.2	72.0	4	19.2
JN-3	N/A	992	7.89	49.7	6.8	207.2	15.6	0	129.4	445.3	57.6
JN-4	N/A	768	7.95	39.3	7.4	215.6	11.3	0	136.7	294.6	44.2
JN-5	N/A	1,260	7.79	54.3	6.9	406.0	18.8	0	107.4	574.3	90.3
JN-6	N/A	160	8.00	16.8	7.3	23.2	2.0	0	131.8	1.1	19.2
JN-7	N/A	164	7.89	13.0	6.9	27.4	2.7	0	140.3	1.4	15.4

Table 2. (continued).

Field #	Lab #	mg/l	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄
						mg/l					
P1	N/A	484	8.20	28.0	7.3	68.7	1.9	0	183.1	20.5	79.3
P2	N/A	1,116	7.71	22.0	0.5	333.6	23.5	0	106.8	88.3	497.1
P3	N/A	1,024	8.16	23.2	0.8	318.6	21.1	0	103.7	87.6	480.0
P4	N/A	1,608	7.84	67.3	5.3	493.1	27.8	0	118.9	111.3	893.4
P5	N/A	1,660	8.08	159.3	34.9	231.7	9.0	0	209.3	181.9	956.3
P10	N/A	1,708	8.18	67.9	17.1	366.2	6.3	0	255.0	133.6	939.0
P13	N/A	756	7.90	38.3	2.7	105.5	3.1	0	237.9	16.7	298.7
P14	N/A	668	8.00	47.9	4.4	71.0	2.7	0	209.3	23.0	289.6
P15	N/A	868	8.07	78.6	12.6	152.2	5.9	0	201.4	80.5	484.7
P20	N/A	632	8.02	43.2	4.1	97.0	2.3	0	192.2	21.3	305.0
P22	N/A	600	7.90	49.3	4.4	111.3	2.7	0	192.2	38.6	311.7
P23	N/A	640	8.08	18.6	2.4	120.2	1.6	0	250.2	29.1	308.3
P24	N/A	1,348	7.92	38.5	1.8	371.4	18.0	0	275.8	79.1	765.5
P25	N/A	604	8.35	38.1	5.7	78.8	3.5	0	183.1	8.9	285.8
W-1	N/A	952	7.75	28.8	8.6	225.5	15.2		320.9	88.6	280.5
W-2	N/A	1,236	8.25	46.3	16.4	405.8	26.2	14.4	439.3	318.7	222.9
W-3	N/A	720	8.66	10.2	7.2	253.0	10.6	37.2	334.4	82.2	132.6
W-4	N/A	552	8.50	8.2	8.3	180.7	16.8	25.2	335.6	54.2	94.1
W-5	N/A	784	8.00	9.0	7.5	255.4	14.1	0	317.3	77.6	263.2
W-6	N/A	888	7.93	20.0	10.0	286.4	14.1	0	358.8	83.7	253.9
W-7	N/A	604	8.36	3.0	5.8	218.8	0.4	22.8	369.8	41.5	130.6
W-8	N/A	840	7.94	24.8	13.0	238.8	0.8	0	454.0	79.1	146.0
W-9	N/A	604	9.26	21.4	6.3	236.1	8.2	90.0	263.6	95.7	105.7
W-10	N/A	2,100	8.60	264.1	48.2	414.5	22.7	7.2	46.4	314.4	1219.9
W-11	N/A	1,860	7.56	345.7	80.6	64.6	7.0	0	145.2	19.1	1114.3
W-12	N/A	1,392	7.54	322.2	80.0	72.4	7.4	0	119.6	30.1	1085.5
W-13	N/A	1,848	7.49	240.5	113.3	140.2	5.1	0	175.7	90.4	1027.9
W-14	N/A	1,328	7.69	123.8	70.6	176.5	3.9	0	179.4	129.0	624.4
W-15	N/A	1,224	7.81	110.8	50.8	164.8	9.4	0	120.8	25.2	979.8
W-16	N/A	2,480	7.15	472.7	14.7	197.2	9.8	0	52.5	22.0	1498.6
W-17	N/A	1,968	7.94	321.4	49.0	152.4	9.0	0	45.1	20.6	1181.6
W-18	N/A	2,616	7.59	502.8	29.2	144.1	11.7	0	43.9	20.2	1575.4
W-19	N/A	2,120	8.87	155.7	58.3	388.5	72.3	27.6	37.8	229.7	1018.2
W-20	N/A	372	8.35	36.9	17.9	32.2	5.5	1.2	197.7	20.9	44.2
W-21	N/A	548	7.85	36.9	30.4	65.0	4.7	0	328.3	31.5	61.5
W-22	N/A	364	7.57	43.9	19.8	33.8	4.7	0	225.8	19.8	48.0
W-23	N/A	344	8.21	40.3	18.3	52.9	0.8	0	248.9	23.7	63.4
W-24	N/A	616	8.75	5.6	1.6	265.1	4.3	13.2	428.3	50.7	50.0
W-25	N/A	348	8.59	8.4	4.2	120.0	17.6	0	299.0	14.2	50.0
W-26	N/A	728	9.02	2.6	1.1	271.0	5.5	42.0	454.0	42.9	126.8
W-27	N/A	500	8.50	8.4	8.0	170.6	16.4	13.2	333.2	46.4	80.7
W-28	N/A	768	8.44	24.4	8.6	232.0	12.1	0	222.7	178.0	178.7
W-29	N/A	228	7.49	48.9	7.8	18.6	1.2	0	109.8	3.2	96.1
W-30	N/A	1,436	7.83	270.0	39.8	71.0	3.9	0	158.6	80.1	739.7
W-31	N/A	616	8.95	15.8	6.1	211.7	5.5	21.6	234.3	70.9	186.4
W-32	N/A	720	8.53	19.2	6.3	242.1	7.8	0	379.5	67.0	194.0
W-33	N/A	720	9.42	10.0	2.1	233.3	16.8	69.6	371.0	29.4	101.8
W-34	N/A	604	10.56	3.6	2.3	190.1	20.3	199.2	41.5	23.7	71.1
W-35	N/A	556	8.66	9.6	5.5	196.8	14.1	13.2	458.9	22.3	59.6

Table 3. Analysis of iron, fluoride, boron, phosphorous and silica for selected thermal waters in New Mexico and west Texas.

Field #	Lab #	Fe	F	B	P	SiO ₂
ppm						
JW-1		<.10	1.05	.04	.02	14.50
JW-2		<.10	.72	.03	.02	45.35
JW-3		<.10	1.43	.28	.02	75.18
JW-4		<.10	1.49	.22	.01	64.80
JW-5		<.10	1.80	.38	.01	90.94
JW-6		<.10	.51	.02	.02	26.33
JW-7		<.10	.62	.04	.01	29.31
1P		1.10	.35	.08	.01	31.3
2P		.20	12.6	.48	.02	147.5
3P		.40	12.0	.50	.02	143.0
4P		.83	7.25	.42	.01	115.6
5P		<.10	3.55	.25	.01	42.3
10P2		.53	7.25	.51	.01	60.7
13P		1.31	3.90	.10	.01	74.1
14P		.16	.85	.06	.01	48.4
15P		<.10	2.35	.18	.01	34.3
20P		<.10	2.65	.10	.01	50.4
22P		<.10	1.20	.06	.01	43.3
23P		7.66	1.15	.12	.01	29.3
24P		21.18	9.35	.50	.01	149.7
25P		.36	3.55	.12	.01	34.3
W-1	N/A	.20	2.68	.99	.02	69.5
W-2	N/A	.04	1.36	1.02	.02	73.8
W-3	N/A	.12	2.15	.67	.02	55.6
W-4	N/A	.10	2.15	.42	.02	58.8
W-5	N/A	.15	2.24	.55	.01	47.1
W-6	N/A	.42	2.68	.69	.02	65.2
W-7	N/A	.42	3.67	.35	.05	37.9
W-8	N/A	.34	2.68	.33	.02	47.1
W-9	N/A	.01	2.68	.29	.02	4.3
W-10	N/A	.21	1.40	.74	.01	8.3
W-11	N/A	1.24	.86	.14	.01	28.4
W-12	N/A	.88	.78	.16	.01	26.5
W-13	N/A	2.24	1.00	.25	.01	27.4
W-14	N/A	1.94	1.26	.35	.01	23.3
W-15	N/A	.30	1.11	.55	.01	48.1
W-16	N/A	.90	1.07	.27	.01	14.3
W-17	N/A	.10	.93	.16	.01	13.3
W-18	N/A	2.96	1.15	.23	.01	68.4
W-19	N/A	.62	1.50	.90	.01	43.0
W-20	N/A	.88	.86	.10	.02	66.3
W-21	N/A	.46	1.04	.10	.02	68.4
W-22	N/A	.25	.67	.07	.02	65.2
W-23	N/A	<.15	.80	.14	.04	41.9
W-24	N/A	.61	2.50	.76	.02	19.5
W-25	N/A	1.43	2.50	.32	.03	41.9
W-26	N/A	.29	8.00	.90	.28	53.5
W-27	N/A	<.15	2.25	.41	.04	63.1
W-28	N/A	1.00	1.65	.47	.07	77.0
W-29	N/A	.27	1.15	.05	.02	33.6
W-30	N/A	<.15	2.50	.15	.01	39.8
W-31	N/A	<.15	2.65	.40	.01	39.8
W-32	N/A	<.15	2.05	.55	.10	52.4
W-33	N/A	<.15	3.30	.49	.02	93.5
W-34	N/A	.15	1.85	.25	.02	85.8
W-35	N/A	2.94	1.40	.21	.05	39.8
W-36	N/A	.83	3.00	.73	.01	48.1
B1	N/A	.12	.67	.12	.01	46.2
B2	N/A	.49	4.44	.86	.02	69.9
B3	N/A	.49	.57	.22	.01	35.4
B4	N/A	.53	.45	.23	.03	63.9
B5	N/A	<.10	5.90	.34	.01	31.3
B6	N/A	<.10	5.90	.37	.02	32.3
B7	N/A	<.10	1.48	.08	.02	28.9
B8	N/A	1.25	.64	.69	.03	44.3
B9	N/A	.38	1.49	.38	.01	44.3
B10	N/A	<.10	3.10	.35	.01	44.3

Table 3. (continued).

Field	Lab #	Fe	F	B	P	SiO ₂
ppm						
B11	N/A	<.10	3.10	.35	.01	44.3
B12	N/A	<.10	2.46	.20	.05	37.3
B13	N/A	<.10	2.02	.09	.02	25.3
B14	N/A	<.10	.69	.09	.02	21.3
B15	N/A	.12	1.73	.08	.01	32.1
B16	N/A	.36	.27	.07	.06	44.3
B17	N/A	<.10	3.10	.09	.01	35.3
B18	N/A	<.10	2.86	.10	.01	34.2
B19	N/A	<.10	3.20	.38	.01	31.3
B20	19	.16	2.70	.30	0	26.87
B21	20	.14	4.10	2.22	0	8.99
B22	21	1.28	2.50	1.96	.02	16.04
B23	22	.32	1.10	.18	0	29.07
B24	23	<.10	1.20	.09	0	26.87
B25	24	.22	.25	.02	0	23.58
B26	25	<.10	.11	0	.01	36.80
B27	26	<.10	.11	0	.01	36.80
B28	27	1.15	2.70	0	0	50.12
Gila 1	28	<.10	.53	0	0	42.06
Gila 2	29	.12	6.10	.01	.01	45.16
Gila 3	30	.25	3.10	.02	0	41.03
Gila 4	31	<.10	16.00	0	0	55.56
Gila 5	32	<.10	8.70	.03	0	72.27
Gila 6	33	<.10	8.60	.02	0	73.31
Gila 7	34	.22	9.50	.07	0	85.89
Gila 8	35	1.25	8.70	.11	.01	85.89
Gila 9	36	.29	.61	.01	0	59.73
Gila 10	37	3.11	.66	.01	0	60.78
Gila 11	38	<.11	3.00	.01	0	54.53
LD1	132	<.15	3.66	.46	0	33.52
LD2	133	<.15	6.90	.46	.01	39.64
LD3	134	<.15	.44	.32	.01	43.36
LD4	135	.37	2.67	.50	.01	32.30
LD5	136	<.15	7.11	.64	.01	47.15
LD6	137	.62	.30	.12	.01	38.08
LD7	138	4.70	.16	.12	.02	47.62
LD8	139	6.39	1.34	.06	.01	45.23
LD9	140	<.15	.12	.04	.14	47.62
LD10	141	.56	.11	.04	.01	39.28
LD12	143	<.15	.18	.06	.01	35.68
LD13	144	<.15	.14	.06	.01	39.28
LD14	145	.56	.31	.10	.01	14.23
LD15	146	1.49	.42	.08	.01	47.62
LD16	147	.22	.22	.08	.01	41.65
LD17	148	1.91	.16	.08	0	44.03
LD18	149	.78	2.26	.12	0	42.85
Gila 20	150	.31	9.45	.12	.01	67.65
Gila 21	151	<.15	7.65	.08	.01	50.00
Gila 22	152	<.15	11.85	.12	0	68.91
Gila 23	153	.25	10.50	.92	0	21.39
Gila 24	154	<.15	5.85	.16	0	34.51
Gila 25	155	<.15	7.35	.44	0	47.62
Gila 26	156	<.15	3.00	.14	.01	49.40
Gila 27	157	<.15	19.05	2.56	.01	63.73
Gila 28	158	<.15	1.00	.12	.01	52.95
Gila 29	159	<.15	.49	.14	.23	57.75
Gila 30	160	.49	18.45	.42	.06	48.22
MFG1	161	.37	4.86	.05	.20	51.0
MFG2	162	.42	5.28	.02	.16	56.0
MFG3	163	<.10	5.28	.07	.09	56.5
MFG4	164	<.10	5.07	0	.09	54.0
W-50	238	<.10	1.02	.22	.01	22.5
W-51	239	.30	3.00	.42	.01	6.3
W-52	240	<.10	7.50	.69	.02	41.0
W-53	241	<.10	1.80	.74	.01	22.0
W-54	242	.27	3.66	1.18	.02	85.5
W-55	243	.19	2.16	.78	.02	57.0

Table 3. (continued).

Field #	Lab #	Fe	F	E	P	SiO ₂
ppm						
W-56	244	<.10	.81	.23	.01	26.0
W-57	245	22.5	2.28	.80	.01	24.0
W-58	246	.21	2.52	1.08	0	39.5
W-59	247	2.62	2.85	.87	.04	45.0
W-60	248	177.0	1.08	.18	.02	34.5
W-61	249	.23	.22	.38	.01	16.2
W-62	250	.33	3.66	1.57	.01	24.0
W-63	251	.96	3.48	3.51	.02	28.0
W-64	252	.64	3.99	2.00	.01	94.5
W-65	253	.16	.99	.71	.03	37.0
W-66	254	.62	5.82	3.13	0	21.5
W-67	255	1.71	3.48	3.40	.02	28.5
W-68	256	.82	3.99	1.78	.02	98.5
W-69	257	<.10	8.25	1.56	.04	39.0
W-70	258	1.04	6.15	2.91	.02	29.7
W-71	259	7.41	1.71	.91	0	29.5
W-72	260	.50	.93	.78	.03	39.0
W-73	261	.20	2.52	.45	0	59.0
W-74	262	.49	2.52	.21	.03	31.7
W-75	273	.54	1.08	.14	0	49.5
W-76	274	.31	.90	.10	.02	56.2
W-77	275	6.84	1.23	.23	.02	52.0
W-78	276	<.10	1.50	.30	.01	66.5
W-79	277	.25	2.16	.53	0	71.0
W-80	278	1.62	1.50	.48	.04	42.0
W-81	279	.76	1.71	.76	.02	37.5
W-82	280	1.00	.43	.78	.01	40.0
W-83	281	<.10	.33	1.36	.03	15.5
W-84	282	<.10	1.54	.22	0	58.5
AN 1	283	<.10	1.60	.12	.05	58.5
AN 2	284	14.3	.95	.17	.01	15.5
AN 3	285	14.92	.66	.02	.04	68.5
AN 4	286	<.10	2.85	.59	.01	97.5
AN 5	287	<.10	3.48	.18	.01	50.5
AN 6	288	74.58	1.98	.78	0	30.0
AN 7	289	1.73	2.28	.17	0	29.5
AN 8	290	3.01	1.14	.05	0	33.5
AN 9	291	47.69	.84	.01	0	.95
AN10	292	8.54	.63	.02	0	37.5
AN11	293	<.10	2.85	.19	0	44.5
AN12	294	10.31	2.28	0	.01	45.0
AN13	295	21.85	3.03	.12	.02	32.0
AN14	296	<.10	3.45	.04	.01	44.0
AN15	297	17.98	.63	0	0	30.0
AN16	298	.29	1.32	0	.01	37.0
AN17	299	<.10	4.02	.13	.01	30.0
AN18	300	<.10	1.71	.18	.01	37.5
AN19	301	3.63	Not enough	.04	.01	40.0
AN20	302	.68	.69	.05	0	49.5
AN21	303	<.10	3.81	.04	.01	37.5
AN22	304	.83	2.16	.05	.01	32.5
AN23	305	.65	.93	0	.01	37.0
	306	<.10	5.01	0	.01	49.5
	307	<.10	5.01	0	.01	50.0
	308	<.10	.75	0	0	28.0
	309	<.10	2.07	.02	.04	39.5
	310	<.10	.46	0	.03	25.0
NM 1	381	<.10	20.70	.47	<.01	72.5
NM 2	382	<.10	.67	.50	.01	72.5
NM 3	383	.34	.64	.56	<.01	69.0
NM 4	384	<.10	.66	.70	<.01	71.0
NM 5	385	.24	.67	.67	<.01	75.0
NM 6	386	<.10	.67	.50	.01	72.0
NM 7	387	.34	4.65	.28	.01	8.2
NM 8	388	8.72	.43	.29	<.01	15.0
NM 9	389	4.63	1.02	.25	<.01	19.0
NM10	390	2.41	.95	.04	<.01	18.0

Table 3. (continued).

Field #	Lab #	Fe	F	B	P	SiO ₂
ppm						
NM11	391	3.60	.90	.20	.01	14.0
NM12	392	.47	.43	.06	.01	19.5
NM13	393	5.70	1.16	.43	.01	10.5
NM14	394	.47	1.46	.15	.05	13.0
NM15	395	.10	1.31	.40	.05	23.0
NM16	396	<.10	1.30	.57	.05	23.0
NM17	397	<.10	1.32	.58	.05	22.5
NM18	398	<.10	1.31	.33	.03	21.5
NM19	399	.10	14.70	1.30	.03	65.0
NM20	400	<.10	1.01	1.50	.06	66.0
NM21	401	.14	1.12	1.35	.01	74.0
NM22	402	1.08	12.60	.55	.01	54.5
NM23	403	<.10	.58	.10	.01	27.0
NM24	404	.37	.35	.15	.01	35.0
NM25	405	<.10	1.25	0	.14	35.0
NM26	406	.14	<.20	0	.01	13.5
NM27	407	<.10	1.25	0	.01	35.5
NM28	408	.19	1.17	0	.01	33.0
NM29	409	.64	2.74	.29	.01	59.5
NM30	410	<.10	1.64	.22	.02	60.0
NM31	411	<.10	2.49	.23	.02	67.0
NM32	412	3.76	.23	.12	<.01	31.0
NM33	413	<.10	3.41	1.66	.01	61.0
NM34	414	<.10	2.09	0	.01	40.5
PV 1	415	.10	1.16	.71	.01	20.0
PV 2	416	.17	1.27	.61	.01	34.0
PV 3	417	1.13	.53	0	.01	29.5
PV 4	418	.42	.58	.12	.01	31.5
PV 5	419	11.53	.86	.33	0	11.5
PV 6	420	19.60	3.54	.84	0	15.0
PV 7	421	.64	1.74	1.33	0	29.0
PV 8	422	.57	.58	.18	.01	27.0
PV 9	423	3.59	.57	.24	0	25.5
PV10	424	.84	.73	0	.01	24.5
PV11	425	1.25	1.63	.04	0	19.0
T 1	426	<.10	.27	.30	.01	31.0
T 2	427	9.21	3.0	.54	.01	9.0
T 3	428	.24	2.96	.76	.01	18.0
T 4	429	<.10	.96	.10	.01	36.5
T 5	430	<.10	5.37	.20	.01	9.5
T 6	431	2.39	2.91	.88	.01	40.5
T 7	432	.14	1.78	.06	.01	34.5
T 8	433	.44	3.74	.18	.01	50.0
T 9	434	11.53	1.93	.42	.01	43.0
T10	435	8.11	.67	.94	.01	4.8
T11	436	.67	2.54	.30	.01	43.5
T12	437	.31	1.23	1.52	.01	16.5
T13	438	.66	1.98	.82	.02	1.9
T14	439	<.10	.42	.08	.02	21.5
T15	440	.13	1.17	.18	.02	17.5
NM50	441	2.52	.45	.20	.06	9.1
NM51	442	<.10	.29	.05	.01	21.5
NM52	443	1.63	.20	.04	.01	12.5
Stromberg	444	<.10	.26	-	.04	23.25
RK 1	445	<.10	.24	.10	.03	16.0
RK 2	446	.22	.20	.20	.13	17.0
RK 3	447	<.10	.19	.15	.09	20.5
RK 4	448	<.10	.22	.19	.03	19.0
RK 5	449	3.47	.19	.15	.01	15.0
RK 6	450	<.10	.22	.10	.07	21.0
RK 7	451	.15	.27	.17	.01	26.5
RK 8	452	.20	.23	.15	.04	26.0
RK 9	453	<.10	.38	.15	.03	15.0
RK10	454	<.10	.25	.14	.07	20.0
RK11	455	<.10	.53	.13	.02	16.5
RK12	456	<.10	.21	.13	.07	17.5
RK13	457	.42	.56	.28	.02	23.5
RK14	458	<.10	.39	.16	.01	32.0

Table 3. (continued).

Field #	Lab #	Fe	F	B	P	SiO ₂
ppm						
RK15	459	<.10	.36	.15	.01	21.5
RK16	460	.36	.34	.19	.01	27.0
RK17	461	26.15	.84	.31	.01	4.0
RK18	462	.45	.84	.18	0	17.0
RK19	463	<.10	1.77	.05	0	17.0
RK20	464	2.18	.47	.35	0	30.0
RK21	465	.26	.48	.38	.01	24.0
RK22	466	11.93	.46	.35	0	12.2
RK23	467	3.24	1.58	.19	0	12.5
RK24	468	<.10	1.65	.18	.02	46.0
RK25	469	1.80	.67	.10	.01	21.5
W85	539	<.10	6.00	.50	.01	45.5
W86	540	<.10	5.00	.40	.01	53.0
W87	541	<.10	1.25	.40	.01	18.5
W88	542	<.10	2.92	.40	.05	39.0
W89	543	<.10	1.15	.35	.01	30.5
GC 1	544	.10	.88	3.90	<.01	17.5
GC 2	545	30.37	.59	1.00	.01	15.0
GC 3	546	0.82	.90	0.55	0	37.0
GC 4	547	0.19	.47	0.20	0	14.0
GC 5	548	0.35	<.20	0.15	0	13.5
SA 1	549	0.53	3.15	0.75	0	20.0
SA 2	550	<.10	<.2	0.15	0	10.0
SA 3	551	<.10	<.2	0.15	0	11.5
SA 4	552	<.10	<.2	0.15	0	8.7
SA 5	553	<.10	<.2	0.15	0	9.4
SA 6	554	2.91	.42	0.12	0	11.0
SA 7	555	1.28	<.2	0.12	0	8.8
SA 8	556	0.24	.82	0.15	0	16.5
SA 9	557	3.60	2.30	0.60	0	15.5
SA10	558	0.06	0.73	0.15	0	12.0
SA11	559	10.60	1.60	0.28	0	12.5
SA12	560	0.84	1.52	0.40	0	16.0
SA13	561	<.10	1.10	0.18	0	16.0
SA14	562	<.10	1.30	0.30	0	19.5
SA15	563	<.10	1.05	0.15	0	24.0
SA16	564	0.84	1.00	1.40	0	21.0
SA17	565	<.10	0.40	0.15	0	15.0
SA18	566	4.73	0.70	0.18	0	22.0
SA19	567	0.21	1.60	0.20	0	16.5
SA20	568	<.10	0.20	0.10	0	8.2
US98	569	<.10	0.50	0.10	.10	40.5
US99	570	0.19	<.20	0.10	.13	49.0
US100	571	<.10	2.20	0.10	.40	57.0
US101	572	.10	1.85	0.20	.14	33.5
US102	573	0.21	1.20	0.25	.08	26.5
US90	574	0.42	0.34	0.10	.03	30.0
US91	575	.10	0.56	0.10	.01	44.0
US92	576	0.44	0.73	0.10	.03	39.5
US93	577	.10	1.40	0.25	.03	40.0
US94	578	.10	1.60	0.15	.10	39.5
US95	579	0.33	0.27	0.05	.01	48.0
US96	580	1.88	.20	0.30	.64	22.0
US97	581	0.37	.20	0.10	.06	27.5
US98	582	.10	1.45	0.25	.01	67.5
US105	583	0.33	0.48	0.20	.01	30.0
US106	584	0.19	1.20	0.25	.03	41.0
US107	585	1.64	0.73	3.00	.10	10.0
US108	586	<.10	1.40	0.40	.06	28.5
US109	587	<.10	0.25	0.20	.49	33.5
US110	588	0.19	0.98	0.20	.01	10.5
NM53	589	0.55	2.40	.40	.03	26.0
NM54	590	0.20	<.20	.05	.03	23.0
NM55	591	0.20	0.72	.05	.06	25.5
GC100	592	12.50	2.40	.15	.32	30.0
GC101	593	3.85	1.10	.15	.02	16.5
GC102	594	0.15	<.20	.05	.02	21.5

Table 4. Analysis of nitrogen, nickel, lead, antimony, selenium, strontium and zinc for selected thermal waters in New Mexico and west Texas.

Field #	Lab #	NO ₃ + NO ₂	Ni	Pb	Sb	Se	Sr	Zn
ppm								
JW-1		5.23	<.03	.027	<.5	.003	.12	.17
JW-2		.60	<.03	.006	<.5	.002	<.04	.14
JW-3		.96	<.03	.021	<.5	.006	.33	.14
JW-4		1.05	<.03	.018	<.5	.005	.28	.15
JW-5		.96	<.03	.042	<.5	.007	.43	.12
JW-6		2.12	<.03	.004	<.5	.002	.03	.14
JW-7		1.88	<.03	.005	<.5	.020	.04	.12
3P		.66	<.03	.242	<.5	.006	.47	.10
26P		40.00	<.03	.031	<.5	.003	.54	.48
B 1	N/A	5.57	<.03	.070	<.5	.005	1.28	.64
B 2	N/A	.47	<.03	.844	<.5	.038	2.49	.10
B 5	N/A	.08	<.03	.090	<.5	.006	.86	.09
B 6	N/A	1.00	<.03	.139	<.5	.009	.83	.06
B 9	N/A	2.12	<.03	.202	<.5	.018	4.10	.05
B10	N/A	1.88	<.03	.200	<.5	.017	4.12	.07
B11	N/A	2.01	<.03	.105	<.5	.015	4.19	.09
B12	N/A	11.14	<.03	.623	<.5	.009	2.21	.12
B13	N/A	1.63	<.03	.025	<.5	.003	.35	.16
B14	N/A	1.82	<.03	.033	<.5	.004	.39	3.58
B17	N/A	.84	<.03	.008	<.5	.004	.28	.09
B18	N/A	.40	<.03	.005	<.5	.004	.38	.09
B19	N/A	1.40	<.03	.257	<.5	.029	4.08	.10
Gila 1	28							
Gila 2	29	0	<.13	.014	<.6	.004	.10	<.028
Gila 3	30							
Gila 4	31	0	<.13	.051	<.6	.004	<.02	<.028
Gila 5	32	.29	<.13	.024	<.6	.005	.02	.06
Gila 6	33	.19	<.13	.021	<.6	.005	.02	.06
Gila 7	34	.19	<.13	.021	<.6	.006	.03	<.028
Gila 8	35	0	.13	.021	.6	.006	.02	.05
Gila 9	36							
Gila 10	37							
Gila 11	38							
LD 1	132	4.48	<.16	.005	<.5	.005	.03	<.02
LD 2	133	.19	<.16	.009	<.5	.009	.15	<.02
LD 3	134	42.65	<.16	.006	<.5	.016	.46	.21
LD 4	135	15.30	<.16	.006	<.5	.008	.07	.33
LD 5	136	15.02	<.16	.008	<.5	.010	.04	.05
LD 6	137	4.93	<.16	.001	<.5	<.002	.06	.13
LD 7	138	7.12	<.16	.039	<.5	<.002	.03	2.68
LD 8	139	22.75	<.16	.006	<.5	<.002	.02	1.22
LD 9	140	9.77	<.16	.001	<.5	.002	.02	<.02
LD10	141	1.47	<.16	.001	<.5	.002	.03	.20
LD11	142	2.15	<.16	.004	<.5	<.002	<.02	.44
LD12	143	0	<.16	.001	<.5	<.002	.03	.04
LD13	144	3.70	<.16	.001	<.5	<.002	<.02	.03
LD14	145	3.59	<.16	.002	<.5	.003	<.02	.17
LD15	146	4.88	<.16	.002	<.5	<.002	.03	.73
LD16	147	7.97	<.16	.001	<.5	<.002	.02	.21
LD17	148	1.28	<.16	867.5	3.19	<.002	.03	.63
LD18	149	7.53	<.16	.025	<.5	.002	.03	.17
Gila 20	150	.72				<.002		<.02
Gila 21	151	.15				.003		.03
Gila 22	152	.06				.003		<.02
Gila 23	153	6.72				.003		.14
Gila 24	154	.17				.003		<.02
Gila 25	155	2.00				.004		.03
Gila 26	156	.59				.003		.22
Gila 27	157	0				.006		.04
Gila 29	159	.89				.003		<.02
Gila 30	160	1.47	<.16	.008	<.5	.006	.03	.07
NM 1	381	0	<.15	.003	<.5	.003	.03	<.02
NM 5	385	.77	<.15	.005	<.5	.003	.02	<.02
NM15	395	1.78	<.15	.002	<.5	.006	.87	<.02
NM16	396	.91	<.15	.002	<.5	.005	.86	<.02
NM18	398	.90	<.15	.005	<.5	.006	.85	.02

Table 4. (continued).

Field #	Lab #	NO ₃ +NO ₂	Ni	Pb	Sb	Se	Sr	Zn
ppm								
NM19	399	.20	<.15	.007	<.5	.005	.28	<.02
NM22	402	.10	<.15	.005	<.5	.002	.05	.03
NM27	407	2.11	<.15	.001	<.5	.003	.03	<.02
NM29	409	4.25	<.15	.002	<.5	.003	.13	<.02
NM30	410	0	<.15	.001	<.5	.003	.15	<.05
NM31	411	4.77	<.15	.003	<.5	.003	.12	<.02
NM33	413	.76	<.15	.016	<.5	.007	2.72	<.02
NM34	414	0	<.15	.001	<.5	.003	.02	<.02
T 1	426	24.0	<.15	.002	<.5	.007	<.02	.49
T 2	427	.05	<.15	.011	<.5	.005	2.71	.21
T 3	428	5.40	<.15	.010	<.5	.005	3.77	1.95
T 4	429	.55	<.15	.005	<.5	.004	.13	.15
T 5	430	0	<.15	.010	<.5	.015	4.66	1.50
T 6	431	5.65						
T 7	432	0						
T 8	433	.10						
T 9	434	.05	<.15	.011	<.5	.008	3.15	2.47
T10	435	.05	<.15	.122	<.5	.155	4.53	.75
T11	436	1.10	<.15	.021	<.5	.009	1.02	1.21
T12	437	23.5	<.15	.008	<.5	.042	2.75	6.55
T13	438	.05	<.15	.302	<.5	.007	.94	.17
T14	439	34.0	<.15	.022	<.5	.003	.08	.05
T15	440	1.10		.006		.004		
W85	539	14.50						
W86	540	3.50						
W87	541	22.50						
W88	542	21.00						
W89	543	13.00						
GC 1	544	0.01						
GC 2	545	0						
GC 3	546	0.02						
GC 4	547	2.15						
GC 5	548	2.24						
SA 1	549	0.07						
SA 2	550	0.86						
SA 3	551	0.32						
SA 4	552	0.26						
SA 5	553	0.47						
SA 6	554	0.87						
SA 7	555	0.43						
SA 8	556	3.05						
SA 9	557	2.96						
SA10	558	1.02						
SA11	559	5.20						
SA12	560	12.42						
SA13	561	1.34						
SA14	562	7.00						
SA15	563	2.65						
SA16	564	0.11						
SA17	565	0						
SA18	566	0.20						
SA19	567	0.17						
SA20	568	0.38						
US98	569	0.59						
US99	570	0.47						
US100	571	0.12						
US101	572	0.01						
US102	573	0.14						
US90	574	1.57						
US91	575	0.01						
US92	576	1.58						
US93	577	0.72						
US94	578	0.14						
US95	579	0.21						
US96	580	0.03						
US97	581	0.41						
US98	582	0.35						

Table 4. (continued).

Field #	Lab #	NO ₃ + NO ₂	Ni	Pb	Sb	Se	Sr	Zn
					ppm			
US105	583	0.56						
US106	584	12.54						
US107	585	0.14						
US108	586	0.02						
US109	587	0.04						
US110	588	0.02						
NM53	589	0.06						
NM54	590	0.70						
NM55	591	0.20						
CG100	592	0.20						
CG101	593	4.50						
CG102	594	0.88						

Table 5. Analysis of cadmium, cobalt, chromium, copper, mercury, hydrogen sulfide, lithium, manganese, molybdenum, ammonium, silver, aluminum, arsenic, barium and bromide for selected waters in New Mexico and west Texas.

Field #	Lab #	Cd	Co	Cr	Cu	Hg	H ₂ S	Li	Mn	Mo	NH ₄	Ag	Al	As	Ba	Br
									ppm							
JW-1	N/A	<.01	<.15	<.1	<.10	.0012	<.1	.02	<.07	<.5	.30	<.03	<2.5	.001	<.7	.54
JW-2	N/A	<.01	<.15	<.1	<.10	.0011	<.1	.01	<.07	<.5	.90	<.03	<2.5	.007	<.7	.31
JW-3	N/A	<.01	<.15	<.1	<.10	.0012	<.1	.48	<.07	<.5	.13	<.03	<2.5	.018	<.7	.56
JW-4	N/A	<.01	<.15	<.1	<.10	.0012	<.1	.34	<.07	<.5	1.24	<.03	<2.5	.014	<.7	.43
JW-5	N/A	<.01	<.15	<.1	<.10	.008	<.1	.65	<.07	<.5	1.35	<.03	<2.5	.021	<.7	.56
JW-6	N/A	<.01	<.15	<.1	<.10	.0011	<.1	.04	<.07	<.5	1.16	<.03	<2.5	.002	<.7	.22
JW-7	N/A	<.01	<.15	<.1	<.10	.0006	<.1	.03	<.07	<.5	.69	<.03	<2.5	.002	<.7	.27
3P	N/A	<.01	<.15	<.10	<.10	.0006	<.1	.64	.08	<.50	.30	<.03	<2.5	.019	<.70	.56
26P	N/A	<.01	<.15	<.10	<.10	.0003	<.1	.05	<.07	<.50	.90	<.03	<2.5	.008	<.70	.47
B 1	N/A	<.01	<.15	<.1	<.10	.0006	<.1	.03	<.07	<.5	0	<.03	<.25	.004	<.7	.65
B 2	N/A	<.01	<.15	<.1	<.10	.0008		1.18	<.07	<.5	0	<.03	<.25	.075	<.7	1.54
B 3																
B 4																
B 5	N/A	<.01	<.15	<.1	<.10	.0148	<.1	.36	<.07	<.5	0	<.03	<.25	.012	<.7	.94
B 6	N/A	<.01	<.15	<.1	<.10	.0011	<.1	.35	<.07	<.5	.08	<.03	<.25	.011	<.7	.85
B 7																
B 8																
B 9	N/A	<.01	<.15	<.1	<.10	.0009	<.1	1.21	<.07	<.5	0	<.03	<.25	.020	<.7	.77
B10	N/A	<.01	<.15	<.1	<.10	.0003	<.1	1.23	<.07	<.5	0	<.03	<.25	.019	<.7	.77
B11	N/A	<.01	<.15	<.1	<.10	.0004	<.1	1.24	<.07	<.5	2.01	<.03	<.25	.018	<.7	.75
B12	N/A	<.01	<.15	<.1	<.10	.0005	<.1	.42	<.07	<.5	1.84	<.03	<.25	.013	<.7	.78
B13	N/A	<.01	<.15	<.1	<.10	.0005	<.1	.06	<.07	<.5	.38	<.03	<.25	.041	<.7	.28
B14	N/A	<.01	<.15	<.1	<.10	.0002	<.1	.08	<.07	<.5	.30	<.03	<.25	.037	<.7	.37
B15																
B16																
B17	N/A	<.01	<.15	<.1	<.10	.0003	<.1	.11	<.07	<.5	.30	<.03	<.25	.012	<.7	.23
B18	N/A	<.01	<.15	<.1	<.10	.0003	<.1	.13	<.07	<.5	0	<.03	<.25	.011	<.7	.30
B19	N/A	<.01	<.15	<.1	<.10	.0005	<.1	1.20	<.07	<.5	0	<.03	<.25	.039	<.7	.82
Gila 1	28															
Gila 2	29	<.02	<.18	<.10	<.12	.0006		.16	<.063	<.45	<.05	<.07	<1.10	.009	<.20	<.00
Gila 3	30															
Gila 4	31	<.02	<.18	<.10	<.12	.0006		.11	<.063	<.45	<.05	<.07	<1.10	.006	<.20	<.00
Gila 5	32	<.02	<.18	<.10	<.12	.0033		.26	<.063	<.45	<.05	<.07	<1.10	.007	<.20	<.00
Gila 6	33	<.02	<.18	<.10	<.12	.0007		.26	<.063	<.45	<.05	<.07	<1.10	.008	<.20	<.00
Gila 7	34	<.02	<.18	<.10	<.12	.0005		.43	<.063	<.45	<.05	<.07	<1.10	.006	<.20	<.00
Gila 8	35	<.02	<.18	<.10	<.12	.0006		.31	<.063	<.45	<.05	<.07	3.10	.009	<.20	<.00
Gila 9	36															
Gila 10	37															
Gila 11	38															
LD 1	132	<.02	<.14	<.1		<.0002	<.1	.14	<.05	<.5	<.05	<.06	<1.0	.012	<.20	.53
LD 2	133	<.02	<.14	<.1	<.10	<.0002	<.1	.31	<.05	<.5	<.05	<.06	<1.0	.017	<.20	.67
LD 3	134	<.02	<.14	<.1	<.10	<.0002	<.1	.47	<.05	<.5	<.05	<.06	<1.0	.008	<.20	1.52
LD 4	135	<.02	<.14	<.1	<.10	<.0002	<.1	.13	<.05	<.5	<.05	<.06	<1.0	.018	<.20	.56
LD 5	136	<.02	<.14	<.1	<.10	<.0002	<.1	.23	<.05	<.5	<.05	<.06	<1.0	.017	<.20	.99
LD 6	137	<.02	<.14	<.1	<.10	<.0002	<.1	.03	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.00
LD 7	138	<.02	<.14	<.1	.69	<.0002	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.28
LD 8	139	<.02	<.14	<.1	<.10	<.0002	<.1	.02	<.05	<.5	<.05	<.06	<1.0	.005	<.20	.32
LD 9	140	<.02	<.14	<.1	<.10	<.0002	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.00
LD10	141	<.02	<.14	<.1	.11	<.0002	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.002	<.20	.00
LD11	142	<.02	<.14	<.1	<.10	<.0002	<.1	.02	<.05	<.5	<.05	<.06	<1.0	.006	<.20	.35
LD12	143	<.02	<.14	<.1	<.10	<.0002	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.12
LD13	144	<.02	<.14	<.1	<.10	<.0002	.10	<.02	<.05	<.5	<.05	<.06	<1.0	.017	<.20	.16
LD14	145	<.02	<.14	<.1	<.10	.0004	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.004	<.20	.41
LD15	146	<.02	<.14	<.1	<.10	.0006	.13	<.02	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.23
LD16	147	<.02	<.14	<.1	<.10	.0004	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.003	<.20	.25
LD17	148	<.02	<.14	<.1	<.10	.0009	<.1	<.02	<.05	<.5	<.05	<.06	<1.0	.031	<.20	.23
LD18	149	<.02	<.14	<.1	<.10	.0004	<.1	.11	<.05	<.5	<.05	<.06	<1.0	.007	<.20	.41
Gila 20	150				<.10	.0004	<.1	.06			<.05	<.06	<1.0	.007	<.20	
Gila 21	151				<.10	.0003	<.1	.03			<.05	<.06	<1.0	.004	<.20	
Gila 22	152				<.10	.0004	<.1	.11			<.05	<.06	<1.0	.006	<.20	
Gila 23	153				<.10	.0006	<.1	.13			<.05	<.06	<1.0	.002	<.20	
Gila 24	154				<.10	.0006	<.1	.08			<.05	<.06	<1.0	.006	<.20	
Gila 25	155				<.10	.0006	<.1	.14			<.05	<.06	<1.0	.011	<.20	
Gila 26	156				<.10	.0006	<.1	.15			<.05	<.06	<1.0	.006	<.20	
Gila 27	157				<.10	.0006	<.1	.20			<.05	<.06	<1.0	.015	<.20	

Table 5. (continued).

Field	Lab	CD	Co	Cr	Cu	Hg	H ₂ S	L1	Mn	Mo	NH ₄	NH ₃	Al	As	Ba	Br
GL1A 29	155	<.02	<.14	<.1	<.10	.0006	<.1	.02	.02	<.5	<.06	<.06	.004	<.20	<.20	.15
GL1A 30	160	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 1	381	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 5	385	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 15	395	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 16	396	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 18	398	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 19	399	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 22	402	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 27	407	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 29	409	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 30	410	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 31	411	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 33	413	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
NH 34	414	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 1	426	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 2	427	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 3	428	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 4	429	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 5	430	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 9	436	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 10	435	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 11	436	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 12	437	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 13	438	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 14	439	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
T 15	440	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
W65	539	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
W66	540	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
W67	541	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
W68	542	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
W69	543	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
GC 1	544	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
GC 2	545	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
GC 3	546	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
GC 4	547	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
GC 5	548	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 1	549	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 2	550	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 3	551	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 4	552	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 5	553	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 6	554	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 7	555	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 8	556	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA 9	557	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA10	558	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA11	559	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA12	560	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA13	561	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA14	562	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA15	563	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA16	564	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA17	565	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA18	566	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA19	567	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
SA20	568	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US98	569	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US99	570	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US100	571	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US101	572	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US102	573	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US90	574	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US91	575	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15
US92	576	<.02	<.15	<.05	<.10	.0006	<.1	.22	.46	<.5	<.06	<.06	.014	<.20	<.20	.15

Table 5. (continued).

Field #	Lab #	Cd	Co	Cr	Cu	Hg	H ₂ S	Li	Mn	Mo	NH ₄	Ag	Al	As	Ba	Br
ppm																
US93	577													.017		
US94	578													.016		
US95	579													.004		
US96	580													.003		
US97	581													.003		
US98	582													.014		
US105	583													.012		
US106	584													.007		
US107	585															
US108	586													.017		
US109	587													.005		
US110	588													.006		
NH53	589													.009		
NH54	590													.003		
NH55	591													.008		
GG100	592													.014		
GG101	593													.007		
GG102	594													.004		

Table 6. Additional raw data to supplement preceding data.

NAME	LOCATION	TEMP °C	S10 ₂	Na	K	Ca	Mg	TDS
ppm								
SW 602	32°24.2', 106°51.2'	19.0	26.6	175.0	22.3	218.6	30.6	1324.0
SW 603	32°28.7', 106°55.0'	20.0	32.5	168.3	15.2	92.4	18.5	820.0
SW 604	32°34.1', 107°00.0'	20.0	41.0	795.2	9.0	118.0	37.4	2564.0
SW 605	32°38.2', 107°03.1'	17.5	31.0	252.7	8.6	213.8	34.5	1548.0
SW 606	32°38.2', 107°03.4'	18.0	30.5	248.8	7.4	175.8	35.0	1432.0
SW 607	32°39.2', 107°05.4'	19.0	27.0	157.3	7.0	148.5	22.4	1026.0
SW 608	32°40.3', 107°12.0'	19.0	46.2	890.9	14.9	437.9	99.3	4532.0
SW 609	32°40.2', 107°12.4'	19.0	84.0	100.2	6.3	43.9	10.3	464.0
SW 610	32°36.7', 107°00.8'	17.5	32.0	603.3	39.1	428.1	69.1	3388.0
SW 611	32°35.0', 107°59.6'	17.5	33.0	558.7	41.8	315.0	51.2	2844.0
SW 612	32°36.7', 107°00.4'	18.5	33.0	428.1	29.3	267.9	47.8	2244.0
SW 613	32°36.3', 106°50.8'	26.0	30.5	138.0	4.3	440.9	10.2	2262.0
SW 614	32°29.9', 106°56.2'	19.0	23.8	104.6	4.7	67.7	17.4	560.0
SW 615	32°29.9', 106°56.1'	18.0	34.0	299.6	6.7	123.7	37.3	1396.0
SW 616	32°36.8', 107°01.2'	17.0	25.5	245.5	6.3	124.1	32.8	1220.0
SW 617	32°36.8', 107°01.1'	17.0	28.5	222.5	9.0	168.7	30.3	1200.0
SW 618	32°37.2', 107°01.2'	18.0	25.5	155.4	7.0	108.6	22.9	884.0
SW 619	32°31.5', 106°59.1'	23.5	36.5	218.6	5.5	121.0	26.4	1084.0
SW 620	32°36.2', 107°00.2'	17.5	27.0	432.7	29.7	304.0	52.4	2556.0
SW 621	32°36.2', 107°00.3'	17.0	26.0	479.1	27.4	352.7	58.8	2800.0
SW 622	32°29.9', 106°54.0'	20.0	26.5	178.9	16.4	91.8	14.8	816.0
SW 623	32°36.4', 107°114.1'	32.0	61.0	62.3	5.5	29.7	8.8	312.0
SW 624	32°35.8', 107°09.4'	32.0	64.0	31.0	3.9	40.5	20.1	340.0
SW 625	32°16.4', 107°13.0'	21.0	33.0	186.9	2.0	22.0	6.0	576.0
SW 626	32°22.2', 107°02.7'	22.0	43.5	167.4	7.0	46.1	5.8	644.0
SW 627	32°17.6', 107°18.0'	23.0	65.0	213.1	8.0	38.7	11.9	788.0
SW 628	32°34.2', 107°48.6'	21.0	15.0	215.9	10.2	434.6	13.7	2452.0
SW 629	32°31.8', 107°48.2'	23.0	52.0	93.8	5.1	30.1	18.7	496.0
SW 630	32°34.6', 106°52.1'	28.0	66.0	739.3	8.2	187.2	16.0	1268.0
SW 631	32°34.8', 106°55.3'	26.0	67.5	135.0	7.4	88.0	27.4	884.0
SW 632	32°32.0', 107°09.0'	27.0	52.0	47.6	11.3	79.8	21.9	456.0
SW 633	32°31.8', 106°45.0'	19.5	49.5	151.3	8.2	89.4	48.9	1112.0
SW 634	32°33.6', 106°40.3'	24.0	22.5	172.9	4.3	118.0	66.7	1332.0
SW 635	32°23.6', 106°40.1'	25.0	33.5	42.1	3.1	42.9	11.4	316.0
SW 636	31°58.4', 107°15.2'	30.5	34.0	174.0	43.8	4.6	5.3	512.0
SW 637	32°01.1', 107°15.7'	29.0	58.5	165.1	29.3	9.8	9.5	500.0
SW 638	31°59.8', 107°18.8'	26.5	33.2	165.1	15.6	15.6	10.0	504.0
SW 639	32°02.4', 107°24.9'	24.0	38.5	286.0	2.7	13.0	6.9	748.0
SW 691	31°40.8', 107°40.4'	29.5	37.2	219.8	18.7	19.2	3.9	612.0
SW 692	31°40.8', 107°50.2'	26.0	40.6	139.3	3.1	9.6	3.6	348.0
SW 693	31°40.8', 107°50.0'	26.0	39.2	201.4	5.5	7.2	5.7	576.0
SW 694	31°40.8', 107°40.8'	31.5	59.0	234.5	19.6	31.5	5.1	700.0
SW 695	31°30.6', 107°30.6'	28.5	41.6	356.8	2.3	2.4	1.0	932.0
SW 696	35°00.8', 106°44.6'	19.5	73.0	46.0	5.9	40.5	10.3	312.0
SW 697	37°09.5', 106°41.0'	14.0	35.0	41.6	3.9	58.1	7.5	316.0
SW 698	37°09.6', 106°41.4'	19.0	64.0	40.0	9.0	68.3	12.0	400.0
SW 699	35°07.1', 106°42.6'	29.0	41.0	106.0	1.6	5.4	0.8	288.0
SW 780	32°34.5', 106°59.5'	20.8	32.0	191.7	2.7	3.6	0.2	452.0

Chapter 3

Earthquake Activity in New Mexico, 1849-1977*

Introduction

The description of earthquake activity in New Mexico is divided in three sections. The first section contains a compilation and discussion of reports of felt shocks prior to 1 January 1962. The second section is devoted to results of instrumental studies of earthquake activity in New Mexico from 1962 through 1977. Included in this section is: (1) a compilation of located earthquakes with local magnitudes equal to or greater than 1.5, (2) a discussion of location procedures and errors, and (3) a description of the methods used to calculate magnitudes. The final section describes briefly the geographical distribution of seismic activity and its relation to the geology of the state.

Earthquake Activity Prior to 1962

Information on locations and strengths of earthquakes prior to 1962 is based mostly on non-instrumentally determined values of earthquake intensity. Intensity values are assigned on the basis of reactions and observations of people during a shock and the degree of damage to structures. Given many intensity observations, the point of maximum intensity and the area of perceptibility can be established. Both of these factors, particularly the latter, can be roughly related to the earthquake magnitude (Richter 1958; Slemmons 1965; Wiegel 1970).

A major weakness in determining the strengths and locations of earthquakes from intensity observations is that the method depends on

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population density. In sparsely settled areas like much of New Mexico, moderate shocks may go completely unreported or reported at low intensity values which do not indicate the true strengths of the earthquakes. Even in areas of relatively high population density, as along the Rio Grande Valley, the point of maximum intensity or area of perceptibility may not be defined because of too few observations.

The reliability of the early reports of earthquakes must also be considered. In the case of New Mexico, some of the intensities for strong earthquakes prior to 1900 are based on reports from local residents tens of years after the shocks (Bagg 1904). Newspaper accounts of earthquakes have also been used to estimate earthquake intensity. In most cases, this procedure has proven to be fairly reliable. However, in at least two instances the effects of earthquakes in the Rio Grande Valley at Socorro were exaggerated in stories appearing in newspapers from Albuquerque and El Paso (Sanford 1963; Ashcroft 1974).

Despite the imperfect nature of the non-instrumental data, these data are of considerable value because they are available for a period of time roughly eight times greater than the instrumental data. Summarized in Table 1 is non-instrumental data which indicates the nature of seismic activity in New Mexico prior to 1962.

The earliest report of earthquakes anywhere in New Mexico is a description of an earthquake swarm in the Rio Grande Rift at Socorro by a U.S. Army surgeon (Hammond 1966). The swarm, which contained 22 felt shocks, commenced on 11 December 1848 and lasted until 8 February 1850. No shock in this swarm was reported felt at distances greater than 25 km. Similar sequences of shocks located away from population centers along the Rio Grande Valley or elsewhere in the state could easily have gone unreported before the start of instrumental studies.

For the period 1849 through 1961, Northrop (1961, 1976) cites evidence, primarily from old newspaper files, for over 600 felt earthquakes in the state of New Mexico. About 95 percent of these shocks occurred along a 150 km section of the Rio Grande Rift from Albuquerque to Socorro; the majority occurring in the 75 km of rift from Belen to Socorro. The concentration of reported activity in the latter area cannot be attributed to population density. The population from Belen to Albuquerque has always exceeded the population from Belen to Socorro.

However, it could be argued that Northrop's data in general are influenced by the distribution of population in the state. Population density is higher in the Albuquerque to Socorro section of the Rio Grande Valley than most other sections of the state. To reduce bias arising from the distribution of population, only shocks with maximum reported intensities (Modified Mercalli) of V or greater are listed in Table 1 and plotted in Figure 1.

The primary source of data for Table 1 is Coffman and von Hake (1973). However, when reference to original material indicated these investigators made errors, changes were made. Two examples are an increase in the intensity of the 15 November 1906, shock and a change in the location of the Cerrillos earthquake on 28 May 1918.

Figure 1 and Table 1 indicate most reported earthquakes prior to the beginning of instrumental studies were along the Rio Grande Valley, primarily between Albuquerque and Socorro. The concentration of seismic activity in this belt cannot be attributed to population density inasmuch as some reported shocks, particularly at Socorro, were of sufficient strength to be felt over areas up to $245,000 \text{ km}^2$ (Sanford, Olsen, and Jaksha 1979). Shocks of this strength are unlikely to have gone

Table 1. Earthquakes reported felt in New Mexico prior to 1962 with maximum intensities (Modified Mercalli) of V or greater.

DATE			ORIGINAL TIME			LOCATION		MAX INTENSITY (MODIFIED MERCALLI)
MON	DA	YEAR	HR	MIN	SECS	LAT	LONG	
APR	28	1868	0	0	0.0	34.00	107.00	5.0
APR		1869	0	0	0.0	34.10	107.00	7.0
		1879	0	0	0.0	34.05	107.00	5.0
JUL	6	1886	0	0	0.0	34.00	107.05	5.0
JUL	12	1893	13	30	0.0	35.00	106.40	5.0
SEP	7	1893	0	0	0.0	34.70	106.60	7.0
OCT	7	1895	0	0	0.0	34.50	106.70	5.0
OCT	31	1895	12	0	0.0	34.05	107.05	6.0
	0	1897	0	0	0.0	33.95	107.00	6.0
JAN	20	1904	2	10	0.0	33.95	107.05	6.0
JAN	20	1904	9	0	0.0	34.10	107.10	5.0
JAN	30	1904	12	30	0.0	34.10	107.05	5.0
MAR	9	1904	7	30	0.0	34.10	107.00	5.0
SEP	6	1904	11	30	0.0	34.10	106.95	5.0
JUL	2	1906	10	15	0.0	34.15	107.10	6.0
JUL	12	1906	12	15	0.0	33.95	106.95	7.5
JUL	16	1906	14	0	0.0	34.00	106.95	8.0
NOV	15	1906	12	15	0.0	34.05	106.95	8.0
JUL	18	1913	0	0	0.0	34.00	107.00	0.0
DEC	6	1913	0	15	0.0	34.10	106.80	0.0
MAY	28	1918	11	30	0.0	35.45	106.10	7.0
FEB	1	1919	20	30	0.0	34.00	107.10	5.0
AUG	13	1924	4	23	0.0	36.00	104.50	5.0
DEC	3	1930	21	35	0.0	35.00	106.40	5.5
FEB	3	1931	23	45	0.0	35.10	106.45	5.0
FEB	5	1931	4	48	0.0	35.00	106.45	6.0
JAN	8	1934	1	32	0.0	34.05	107.10	5.0
MAY	7	1934	5	22	0.0	32.70	108.20	5.0
DEC	14	1935	5	33	0.0	34.80	106.80	5.5
DEC	14	1935	1	57	0.0	34.80	106.85	5.5
FEB	21	1935	1	25	0.0	34.50	106.80	6.0
FEB	21	1935	3	5	0.0	34.55	106.80	5.0
SEP	17	1938	17	20	0.0	33.20	108.60	6.0
SEP	20	1938	5	40	0.0	33.25	108.60	5.0
SEP	29	1938	23	34	0.0	33.25	108.65	5.0
NOV	1	1938	1	26	0.0	33.00	108.70	5.5
NOV	27	1938	0	13	0.0	33.20	108.65	5.0
DEC	24	1938	22	7	0.0	33.20	108.70	5.0
JUN	4	1939	1	15	0.0	33.25	108.75	5.0
AUG	4	1941	7	40	0.0	34.15	107.05	5.0
NOV	6	1947	16	50	0.0	35.00	106.40	6.0
MAY	23	1949	7	22	0.0	34.60	105.20	6.0
AUG	3	1952	20	42	0.0	36.50	105.00	5.0
AUG	17	1952	10	45	0.0	35.50	106.20	5.0
OCT	7	1952	9	20	0.0	37.00	106.00	5.0
NOV	3	1954	20	39	0.0	35.10	106.70	5.0
AUG	3	1955	6	39	42.0	37.00	107.30	6.0
AUG	12	1955	16	20	0.0	35.70	106.10	5.0
APR	26	1956	3	30	0.0	35.10	106.30	5.0
JUL	22	1960	15	49	0.0	34.30	106.85	5.0
JUL	23	1960	14	15	0.0	34.35	106.35	6.0
JUL	24	1960	10	37	0.0	34.30	106.60	5.0
JUL	3	1961	7	6	0.0	34.10	106.95	6.0

Figure 1. Locations of earthquakes reported felt in New Mexico prior to 1962.

undetected anywhere in the state regardless of the distribution of population.

A characteristic of the strong Socorro shocks as well as many other known earthquakes in the rift from Albuquerque to Socorro is that they are associated with earthquake swarms. As have been noted for many years, earthquake swarms are observed in the vicinity of active volcanoes and in regions that have had volcanic activity in geologically recent times (Richter 1958). The possible significance of the earthquake swarms in the Rio Grande Rift is that they may be related to injection of magma into the crust.

Listed in Table 2 are parameters for known earthquake swarms in the Rio Grande Rift during the period 1849 through 1961. By far the strongest and longest earthquake swarm was the 1906-07 swarm at Socorro which appears comparable to the Matsushiro swarm which some believe may have been caused by magmatic intrusion at shallow depth (Stuart and Johnston 1975). Although the evidence is not absolutely conclusive, the distribution of isoseismals for the 1906-07 swarm suggests hypocenters beneath the Socorro Mountain horst block, a structural feature in the central part of the rift. Other swarms listed in Table 2 also appear to have originated in the central part of the rift rather than the margins (see Remarks, Table 2). Recent basalt flows, from north of Albuquerque to south of Socorro, are generally confined to the central part of the rift. This observation in conjunction with the location of earthquake swarms may indicate that magma is continuing to be injected into the central part of the rift.

An earthquake swarm comparable to those in the Rio Grande Rift occurred in the Gila National Forest of southwest New Mexico from August to November of 1938 (Neumann 1940).

Table 2. Characteristics of earthquake S swarms in the Rio Grande Rift, 1849 through 1961.

Date	Duration In Months	Location of Nearest Population Center	Number of Reported Shocks	Maximum Intensity (MM) of Strongest Earthquakes	Reference	Remarks
Dec. 11, 1849 to Feb. 8, 1850	2	Socorro	22	IV	Hammond (1966)	Extent of felt region suggests a location beneath Socorro Mountain, an intra-graben horst block.
Sept. 1893	3	Los Lunas	Daily?	VII	Woollard (1968), Coffman and von Hake (1973), Northrop (1976)	One listing (Woollard, 1968), indicates daily shocks at Sabinai (35 km south of Los Lunas) with maximum intensities > V for 3 months.
Jan. 19, 1904 to March 8, 1904	2	Socorro	34	V	Bagg (1904), Woollard (1968)	Newspaper accounts indicate that shocks on Sept. 10, 1904 at Socorro were not a continuation of this swarm.
July 2, 1906 to Jan., 1907	7	Socorro	Daily	VIII(2)	Reid (1911)	Distribution of isoseismals suggests hypocenters beneath Socorro Mountain, an intra-graben horst block.
Dec. 12, 1935 to Dec. 30, 1935	3/4	Belen	>24	V-VI	Neumann (1937), Coffman and von Hake (1973)	At Los Lunas (18 km north of Belen) shocks were much weaker than at Belen. This suggests epicenters near the central part of the rift rather than the margins.

Earthquake Activity After 1961

Prior to 1962, the number of seismographs in New Mexico and bordering states was inadequate to locate all but a few moderately strong earthquakes in the region. This situation changed in late 1961 and early 1962 when stations at Albuquerque (ALQ) and Las Cruces (LCN), New Mexico, and Payson (TFO), Arizona, went into continuous operation. Readings from these stations as well as earlier stations at Tucson (TUC), Arizona, Lubbock (LUB), Texas, and Socorro (SNM), New Mexico, permitted locations of a relatively large number of earthquakes throughout the region.

For the period 1962 through 1972, 211 earthquakes in New Mexico and bordering areas were located by researchers at New Mexico Tech (NMT) (Sanford et al. 1976). About 30 percent of these shocks were also located by the National Earthquake Information Service (U.S. Geological Survey) and the preceding governmental agencies (U.S. Coast and Geodetic Survey and National Oceanic and Atmospheric Administration).

In September, 1973, the number of located shocks in the northern half of New Mexico and southern margin of Colorado jumped sharply when the Los Alamos Scientific Laboratory (LASL) installed an array of continuous recording stations. Another sharp increase in the number of shocks located in central New Mexico occurred in 1976 when the Albuquerque Seismological Laboratory (ASL) installed a permanent array of stations in and around the Albuquerque-Belen Basin. Since 1973, NMT has continued to locate earthquakes but most of these lie in the southern half of New Mexico, west Texas and northern Mexico.

Earthquake Data - 1962 through 1977

Listed in Table 3 are the dates, origin times, locations and magnitudes of earthquakes in New Mexico for the 16-year period from 1962 through 1977. Also listed is the organization, New Mexico Tech (NMT), U.S. Geological Survey (USGS), Los Alamos Scientific Laboratory (LASL) or Albuquerque Seismological Laboratory-USGS (ASL), which determined all earthquake parameters except magnitude. Assignment of magnitude was made by New Mexico Tech following a procedure described later.

The source of the USGS data was a listing by the National Earthquake Information Service. The LASL epicenters were taken from a publication by Cash et al. (1978). Information on earthquakes from ASL was obtained from reports by Jaksha et al. (1978) and Jaksha and Locke (1978).

Table 3 only lists earthquakes whose local magnitudes (M_L) were 1.5 or greater. The limitation on minimum magnitude was made to keep the numbers of listed shocks within reasonable bounds. Workers at NMT, LASL, and ASL have located hundreds of earthquakes with magnitudes less than 1.5 in and bordering the Rio Grande Rift using arrays of seismograph stations. Results of these micro-earthquake surveys are summarized in Sanford, Olsen, and Jaksha (1979).

Another reason for limiting the listing in Table 3 to shocks with $M_L \geq 1.5$ is to reduce the effects of station distribution on the statewide data set. Because the majority of New Mexico seismograph stations from 1962 through 1977 were in or near the Rio Grande Valley, the probability of locating shocks in the central part of the state was higher than elsewhere. A study by Sanford et al. (1976) indicates that the minimum magnitude shock locatable at the outer boundaries of the state throughout the study period, 1962 through 1977, was about 2.2. Therefore a great deal of station bias remains in the data listed in Table 3.

Table 3. Instrumental origin times, epicenters and magnitudes for New Mexico earthquakes from 1962 through 1977.

DATE YR/MO/DAY	ORIGIN TIME MST	LOCATION		NMT	LOCATED BY			NUMBER OF STATIONS	MAGNITUDE [ML]	
		LAT	LONG		USGS	LASL	ASL			
62 1 3	23:29:52.6	35.32	103.64	X				5	2.60	1
62 1 23	15:12:43.8	33.96	106.86	X				3	1.84	2
62 1 24	15:53:14.6	33.96	106.86	X				3	1.50	3
62 3 22	04:23:53.4	34.25	106.51	X				3	1.74	4
62 4 9	23:22:58.0	34.21	106.44	X				3	1.76	5
62 5 2	23:21:17.7	34.22	107.05	X				3	1.56	6
62 6 14	07:27:55.8	35.68	106.74	X				6	1.87	7
62 6 25	02:35:27.3	34.20	106.10	X				3	1.56	8
62 6 27	04:46:16.0	33.95	107.01	X				3	1.63	9
62 9 1	16:15:07.9	37.16	105.66	X				5	2.97	10
62 12 15	20:20:24.3	33.97	106.86	X				4	1.87	11
63 2 22	07:02:08.1	32.42	106.99	X				6	2.47	12
63 2 22	08:53:18.1	32.45	106.94	X				5	1.51	13
63 3 5	14:40:36.3	31.63	107.63	X				4	1.68	14
63 3 8	06:16:40.0	32.45	107.08	X				4	1.56	15
63 3 27	12:54:56.5	32.72	107.82	X				4	1.61	16
63 6 2	03:07:34.6	34.23	106.46	X				9	1.96	17
63 6 6	03:05:33.3	34.60	104.40	X				9	2.74	18
63 7 3	19:06:00.5	31.91	106.90	X				6	1.92	19
63 8 19	00:38:23.4	32.44	107.15	X				5	2.11	20
63 11 25	17:52:33.8	36.54	105.37	X				9	2.41	21
63 12 19	16:47:28.4	35.14	104.13	X				9	2.88	22
63 12 30	08:46:14.6	34.03	106.54	X				3	1.66	23
64 2 11	09:24:31.0	34.35	103.73	X				4	2.49	24
64 3 3	01:26:26.6	34.97	103.59	X				5	2.22	25
64 6 19	05:26:38.8	33.09	105.95	X				5	1.71	26
65 2 3	11:42:34.4	35.10	103.80	X				9	2.92	27
65 3 9	19:04:46.5	33.87	106.90	X				6	2.54	28
65 4 10	07:00:55.0	33.94	107.05	X				7	2.00	29
65 5 27	12:17:44.1	33.90	107.01	X				4	1.82	30
65 5 27	18:50:53.9	34.88	106.73	X				4	2.01	31
65 5 27	18:58:40.9	33.90	106.71	X				4	2.03	32
65 5 29	13:01:54.2	33.87	106.69	X				5	2.03	33
65 6 4	01:58:58.7	34.90	106.81	X				5	1.73	34
65 7 28	03:52:07.4	33.96	106.82	X				7	2.26	35
65 12 22	04:38:53.4	33.60	106.70	X				4	2.59	36
65 12 22	03:33:29.6	34.02	106.78	X				4	2.15	37
65 12 22	04:05:51.9	34.02	106.78	X				3	1.91	38
65 12 29	00:05:24.1	35.03	105.76	X				4	2.65	39
66 1 23	01:56:39.8	36.96	106.95	X				9	4.29	40
66 1 24	20:16:59.3	36.80	108.30		X			6	?	41
66 4 21	14:14:18.7	35.29	103.32	X				8	2.28	42
66 9 9	17:13:58.4	34.70	108.30		X			5	?	43
66 9 17	21:30:13.0	34.94	103.71	X				7	2.23	44
66 9 24	07:33:46.4	36.43	105.08	X				9	2.71	45
66 9 24	08:27:06.6	36.44	105.09	X				9	2.44	46
66 9 25	13:10:41.0	36.34	105.08	X				8	2.75	47
66 9 25	12:22:40.5	36.45	105.14	X				8	2.75	48
66 10 6	06:29:55.0	35.21	104.27	X				8	2.30	49
66 10 6	10:19:08.2	34.04	106.85	X				4	2.35	50
67 1 16	18:14:37.2	34.43	106.85	X				5	1.64	51
67 7 29	05:49:39.5	33.75	106.47	X				6	2.10	52
67 9 29	03:52:48.0	32.27	106.91	X				8	2.04	53
68 3 9	21:54:25.7	32.70	106.05	X				9	2.91	54
68 3 23	11:53:38.7	32.70	106.05	X				6	2.24	55
68 5 2	02:56:43.8	33.02	105.27	X				5	2.58	56
68 5 15	10:13:04.8	34.27	106.84	X				8	2.32	57

Table 3. (continued).

DATE YR/MO/DAY	ORIGIN TIME MST	LOCATION		NMT	LOCATED BY			NUMBER OF STATIONS	MAGNITUDE (ML)	
		LAT	LONG		USGS	LASL	ASL			
68 5 19	11:02:56.6	34.50	107.98	X				8	2.26	58
68 5 29	02:09:02.2	34.39	107.15	X				3	2.47	59
68 7 25	04:54:34.3	33.99	106.85	X				3	1.64	60
68 8 21	23:47:33.0	35.10	107.52	X				4	1.69	61
68 8 22	02:22:25.5	34.33	105.80	X				4	2.66	62
69 1 30	05:17:38.4	34.22	106.75	X				9	3.42	63
69 3 4	21:09:13.9	34.72	105.85	X				3	2.30	64
69 5 28	05:06:22.5	35.45	107.15	X				6	2.53	65
69 6 1	17:18:24.2	34.23	105.18	X				6	1.97	66
69 6 8	11:36:01.9	34.23	105.18	X				8	2.39	67
69 6 28	14:49:11.5	35.26	107.50	X				4	1.55	68
69 7 4	14:43:33.0	36.15	106.13	X				9	2.85	69
69 7 30	02:05:13.0	34.39	106.99	X				3	1.73	70
69 8 23	21:41:54.2	34.70	108.44	X				9	2.66	71
69 9 13	23:05:31.5	36.86	105.98	X				6	2.27	72
70 1 12	11:21:15.1	35.89	103.40	X				7	3.26	73
70 5 22	09:43:35.6	35.64	106.00	X				4	1.53	74
70 7 3	11:41:25.0	34.90	105.91	X				3	1.60	75
70 7 31	11:57:31.2	35.28	106.15	X				8	2.06	76
70 8 7	11:59:06.0	35.40	105.89	X				8	1.97	77
70 11 28	07:46:11.4	35.10	104.61	X				9	1.18	78
70 11 30	05:35:20.5	36.25	105.49	X				8	2.49	79
71 1 4	07:39:07.0	35.10	106.50	X				9	2.55	80
71 1 6	10:56:31.5	34.15	106.79	X				9	2.75	81
71 1 27	07:56:28.3	34.06	106.50	X				8	2.60	82
71 2 13	04:22:55.0	34.18	108.07	X				4	1.79	83
71 2 14	11:26:14.3	35.30	105.78	X				9	2.76	84
71 3 25	02:43:02.4	34.59	106.03	X				3	1.73	85
71 4 28	11:36:52.1	36.13	105.95	X				5	2.74	86
71 5 22	22:31:18.6	35.43	107.70	X				5	2.31	87
71 6 4	03:55:14.7	36.19	106.42	X				8	2.34	88
71 6 24	22:12:36.7	36.70	105.67	X				4	1.28	89
71 12 6	05:18:13.0	36.15	106.11	X				9	2.90	90
71 12 6	05:22:50.0	36.10	106.17	X				6	2.14	91
71 12 6	05:38:04.2	36.09	106.19	X				6	2.03	92
71 12 6	05:14:07.6	36.08	106.14	X				7	2.31	93
71 12 11	02:28:21.4	35.72	105.29	X				3	1.92	94
71 12 23	14:24:37.0	34.42	107.02	X				4	2.04	95
71 12 27	11:08:59.9	35.79	105.96	X				3	1.68	96
72 2 20	23:09:59.5	36.36	104.87	X				3	1.50	97
72 2 20	23:22:51.4	36.35	104.94	X				4	2.21	98
72 2 27	09:11:48.9	34.15	106.81	X				4	1.64	99
72 2 27	15:56:03.9	32.89	106.04	X				5	2.24	100
72 3 24	01:53:33.7	36.17	105.09	X				9	2.67	101
72 3 24	02:03:16.6	36.14	105.15	X				8	2.26	102
72 3 31	20:14:19.8	36.11	106.04	X				5	2.37	103
72 4 15	00:13:28.0	36.58	105.53	X				5	1.74	104
72 5 6	07:35:05.5	35.40	107.46	X				6	2.16	105
72 5 16	22:13:44.8	34.20	106.58	X				4	1.68	106
72 5 20	19:15:45.7	35.40	107.30	X				6	2.70	107
72 7 29	04:35:43.9	32.68	103.98	X				6	2.50	108
72 10 11	14:11:29.4	32.74	107.92	X				5	2.34	109
72 11 24	01:11:33.2	32.03	108.33	X				6	2.72	110
72 12 18	04:07:30.2	35.42	107.16	X				7	2.68	111
73 1 9	05:08:44.0	32.00	107.10	X				3	1.64	112
73 2 3	01:21:38.6	36.85	108.25	X				4	2.13	113
73 2 3	21:54:08.8	36.25	108.17	X				3	1.53	114
73 2 26	10:51:22.7	35.65	103.50	X				4	1.96	115
73 3 17	07:43:09.0	36.14	106.19	X				8	2.15	116
73 3 22	02:45:50.0	31.35	108.50	X				4	2.86	117

Table 3. (continued).

DATE YR/MO/DAY	ORIGIN TIME MST	LOCATION		NMT	LOCATED BY			NUMBER OF STATIONS	MAGNITUDE	
		LAT	LONG		USGS	LASL	ASL		(MI)	
73	7 22	15:22:12.7	33.00	108.10	X			3	2.33	118
73	7 27	02:46:44.7	36.50	108.60	X			3	2.31	119
73	8 5	12:47:11.5	32.40	107.30	X			3	1.66	120
73	9 10	20:29:23.7	34.42	106.85	X			7	2.40	121
73	9 22	23:38:37.1	34.46	106.95	X			8	2.50	122
73	10 10	02:10:59.5	35.60	108.25	X			3	1.83	123
73	11 14	07:56:09.0	36.93	107.00		X		7	2.10	124
73	12 24	02:20:14.9	35.25	107.74		X		16	3.44	125
73	12 24	15:06:12.5	35.52	106.10		X		7	1.80	126
74	1 12	14:14:00.5	35.20	107.60	X			7	1.85	127
74	1 17	23:04:20.8	36.15	106.20		X		7	1.80	128
74	3 13	16:15:29.0	34.50	106.90	X			3	2.20	129
74	3 23	10:44:15.0	36.50	107.08		X		7	1.90	130
74	3 28	22:14:38.4	35.22	107.55		X		7	1.60	131
74	3 28	22:24:40.4	35.22	107.55		X		7	1.50	132
74	4 8	16:13:53.3	34.20	106.80	X			3	1.60	133
74	4 12	18:14:40.7	34.50	107.00	X			3	2.30	134
74	5 4	20:34:45.5	35.55	108.98		X		7	1.70	135
74	5 22	09:53:42.8	35.06	106.70		X		7	1.90	136
74	7 11	11:25:57.0	35.32	107.78		X		7	2.00	137
74	7 31	17:34:46.5	33.10	104.20	X			4	2.30	138
74	8 20	07:33:22.0	34.40	105.80	X			8	2.30	139
74	8 30	22:57:35.2	34.87	107.06	X			8	2.40	140
74	9 20	23:44:08.5	32.80	106.20	X			5	3.00	141
74	9 29	13:13:44.2	32.80	108.65	X			9	3.20	142
74	9 29	14:26:03.0	32.80	108.65	X			3	2.20	143
74	10 11	11:07:25.8	32.80	108.70	X			7	2.30	144
74	10 15	09:36:06.7	33.83	106.58		X		7	1.80	145
74	10 15	10:05:02.4	33.83	106.56		X		7	1.80	146
74	10 15	10:07:57.9	33.85	106.55	X			6	2.00	147
74	10 15	12:47:38.8	35.25	107.08		X		7	2.10	148
74	10 18	04:30:57.3	35.05	106.82		X		7	1.80	149
74	11 1	10:45:49.6	33.80	106.60	X			6	2.00	150
74	11 21	16:22:58.6	32.50	106.10	X			4	2.70	151
74	11 22	14:11:13.2	33.80	105.10	X			5	1.60	152
74	11 28	03:35:20.5	32.63	104.01	X			6	3.80	153
74	12 28	23:24:11.5	35.17	107.37		X		7	2.10	154
75	2 2	20:49:42.6	35.10	103.10	X			8	2.90	155
75	2 9	09:12:35.7	35.18	106.23		X		7	1.50	156
75	3 5	03:48:05.3	34.55	107.12	X			7	2.70	157
75	3 6	07:56:55.9	34.55	107.14	X			6	2.20	158
75	3 7	03:16:13.0	34.55	107.16	X			10	2.80	159
75	3 7	17:36:04.7	34.55	107.16	X			10	2.90	160
75	3 7	16:33:33.9	34.50	106.90		X		7	1.50	161
75	5 10	01:38:14.9	36.92	104.95		X		7	1.50	162
75	5 16	07:26:22.5	36.48	104.70		X		7	1.90	163
75	5 21	04:46:59.0	36.97	107.22		X		7	1.50	164
75	6 21	05:11:35.2	36.08	104.03		X		7	2.00	165
75	6 26	07:03:33.4	36.05	105.45		X		7	2.90	166
75	6 27	01:39:44.7	34.19	106.93	X			6	1.60	167
75	6 28	07:20:24.2	34.20	106.90	X			10	1.90	168
75	7 20	07:47:37.8	34.57	106.73		X		7	1.80	169
75	9 6	03:46:50.4	36.18	106.23		X		7	1.80	170
75	9 10	01:01:44.2	36.73	105.67		X		7	1.50	171
75	9 29	11:09:42.4	36.00	106.87		X		7	2.70	172
75	9 29	13:17:19.2	36.00	106.87		X		7	1.50	173
75	10 10	11:16:55.9	33.30	105.00	X			3	2.00	174
75	10 17	15:45:02.5	35.38	108.20		X		7	1.90	175
75	12 3	10:12:22.8	32.83	108.66		X		14	3.40	176
76	1 5	06:23:32.9	35.84	108.34		X		95	4.10	177

Table 3. (continued).

DATE YR/MO/DAY	ORIGIN TIME MST	LOCATION		NMT	LOCATED BY			NUMBER OF STATIONS	MAGNITUDE [ML]	
		LAT	LONG		USGS	LASL	ASL			
76 1 14	07:01:31.5	34.10	106.80	X				8	2.20	178
76 1 16	22:07:17.3	35.57	107.87			X		1	1.80	179
76 1 25	04:18:27.5	32.00	103.10	X				12	3.20	180
76 3 7	12:18:25.4	35.68	107.98			X		2	1.70	181
76 3 20	18:15:58.0	32.20	103.10	X				5	1.70	182
76 3 27	22:25:22.0	32.20	103.10	X				8	2.00	183
76 4 1	14:40:27.8	33.80	105.90	X				3	1.50	184
76 4 1	11:46:58.0	33.90	106.00	X				9	2.10	185
76 4 1	14:51:17.0	33.90	105.90	X				3	1.50	186
76 4 6	14:09:00.2	33.90	106.00	X				10	2.70	187
76 4 18	02:48:14.5	33.90	106.00	X				6	1.60	188
76 4 30	15:28:45.7	32.00	103.30	X				4	1.50	189
76 4 30	19:51:12.8	32.00	103.20	X				3	1.50	190
76 5 1	11:13:40.7	32.40	103.10	X				8	2.70	191
76 5 2	00:32:26.6	36.28	106.73			X		2	2.20	192
76 5 3	06:52:59.0	32.40	105.60	X				4	2.40	193
76 5 3	04:00:39.9	32.00	103.20	X				4	1.50	194
76 5 3	11:27:40.3	32.00	103.10	X				4	1.50	195
76 5 9	17:18:23.8	32.00	103.20	X				6	1.40	196
76 5 9	03:54:09.0	33.25	106.80				X	2	1.70	197
76 5 21	13:17:35.0	32.30	105.30	X				3	2.30	198
76 6 1	16:40:09.8	36.30	106.20			X		7	1.90	199
76 6 9	17:37:15.0	31.46	106.99				X	2	1.70	200
76 6 24	15:27:32.0	35.62	103.28		X			19	3.00	201
76 6 26	12:55:39.3	36.13	106.27			X		3	1.50	202
76 7 5	12:46:19.4	36.13	106.25			X		2	1.50	203
76 7 7	12:44:35.2	35.08	106.27			X		2	1.50	204
76 8 30	13:07:32.3	33.30	105.70					3	1.50	205
76 9 17	02:17:46.9	32.20	103.10	X				9	2.10	206
76 12 23	08:36:54.0	34.58	105.77				X	2	1.40	207
76 12 31	07:53:46.5	36.72	106.65			X		2	1.80	208
76 12 31	07:53:54.7	36.57	106.67			A		2	1.90	209
77 1 4	18:31:37.6	32.36	106.92		X			10	2.70	210
77 1 4	23:41:58.0	34.03	106.00				X	2	2.40	211
77 1 5	12:13:02.0	34.05	106.00				X	2	1.70	212
77 2 18	14:10:36.8	32.20	103.10	X				4	1.50	213
77 3 5	03:00:54.7	35.92	106.29		X			47	3.70	214
77 3 9	18:35:33.0	35.80	108.17			X		2	1.70	215
77 3 15	10:00:41.3	35.97	106.98			X		2	1.70	216
77 3 20	07:54:09.0	32.20	103.10	X				7	2.10	217
77 4 3	19:26:49.4	36.10	106.25			X		2	1.90	218
77 4 7	05:45:40.5	32.20	103.10	X				8	2.30	219
77 4 22	22:56:37.0	32.20	103.10	X				3	1.70	220
77 4 26	05:03:07.5	32.00	103.10	X				11	2.50	221
77 6 2	06:46:16.3	34.02	107.06	X				7	1.50	222
77 8 19	09:22:05.0	34.01	107.06	X				5	1.90	223
77 8 22	15:10:56.2	35.62	107.23			X		2	1.50	224

The strongest earthquake during the 16-year period occurred at Dulce on the New Mexico-Colorado border on 23 January 1966. This earthquake was followed by a large number of aftershocks (Cash 1971; Hoffman and Northrop 1978) many of which were located by the USGS and NMT. These aftershocks are not listed in Table 3.

Location Procedures and Accuracy

New Mexico Tech. The procedure used by NMT to determine epicenters is a computer adaptation of the graphical arc method using Pn and Pg arrival times. The crustal structure adopted for the location program consists of an upper crust 22.3 km thick with a velocity of 6.15 km/sec, and a lower crust of the same thickness with a velocity of 6.60 km/sec. The upper mantle velocity immediately below the Moho in the crustal model is 8.10 km/sec.

The change in crustal structure over the state is substantial, e.g. total crustal thickness ranges from 30 to 51 km, upper crustal velocities from 5.8 to 6.2 km/sec, and sub-Moho velocities from 7.6 to 8.25 km/sec (Topozada 1974; Olsen et al. 1979). Because the same crustal structure is assumed throughout New Mexico in the NMT location program, systematic errors in the absolute location of epicenters are probable (Sanford et al. 1977). If reading errors are also considered, the mislocation of an event can be substantial. However, it appears likely that about 95 percent of the locations listed in Table 3 are within 20 km of the true locations.

A comparison of earthquake parameters for 21 shocks located by NMT and USGS revealed some rather large differences. The standard deviation of differences in origin time, latitude and longitude were 2.5 seconds, 0.18° and 0.27°, respectively. Location of shocks felt over small areas (28

Nov. 1970; 4 Jan. 1971; and 28 Nov. 1974) by both organizations appears to indicate most NMT locations are probably more accurate than the USGS locations.

A discussion of location errors is important because many geologists and geophysicists are tempted to associate earthquake epicenters with specific faults. The location errors cited above indicate that this procedure would be dangerous. Another reason for being careful about assigning earthquakes to specific faults is the area of fault surface and maximum displacement associated with the majority of earthquakes listed in Table 3. Ninety-eight percent of the shocks have local magnitudes of less than 3.5. An earthquake of 3.5 can be generated by a maximum displacement of about 1 cm over a fault surface of 1 km^2 . Thus, many of the New Mexico earthquakes could have occurred on minor and unknown faults.

Los Alamos Scientific Laboratory. At LASL, two basic computer programs are used for earthquake location: (1) a computer adaption of the graphical arc technique and (2) a modified version of HYPO 71 (Lee and Lahr 1975; Newton et al. 1976). The crustal model used by LASL in their location programs consists of a single layer crust 40 km thick with a velocity of 6.0 km/sec overlying mantle rock with a velocity of 8.0 km/sec. Accuracy of the epicenters are believed to be 3 km for events recorded by four or more stations interior to the LASL network, 10 km for events on the perimeter of the network, and no better than 20 km for shocks outside the network (Sanford, Olsen, Jaksha 1979).

Albuquerque Seismological Laboratory. At ASL, the earthquake epicenters are obtained from the computer program HYPO 71 (Lee and Lahr 1975). The crustal models used for ASL epicenters are: (1) a single layer crust 39 km thick with a velocity of 6.0 km/sec overlying mantle rock with

a velocity of 8.0 km/sec and (2) a two-layer crust, an upper crust 18.6 km thick with a velocity of 5.8 km/sec, and a lower crust 21.3 km thick with a velocity of 6.5 km/sec overlying mantle rock with a velocity of 7.9 km/sec (Jaksha and Locke 1978). Initially the first model was used for shocks outside the Rio Grande Rift and the second model for those within the rift. However, comparisons of solutions using both crustal models indicate differences in space coordinates which are smaller than error estimates for the array. Since 1976, all epicenters are obtained with the second crustal model regardless of the location of the earthquake (Jaksha and Locke 1978). Accuracy of the epicenters are believed to be 2 km for events interior to the ASL network and 10 km for shocks ASL located outside the array.

Depths of Focus

The depths of focus are not known for nearly all shocks listed in Table 3 because the epicenters were not close (one to focal depths) to a recording station. Some of the events located by LASL and ASL within their arrays may have reasonably accurate depths of focus. Original listings of hypocenters by LASL (Cash et al. 1978) and ASL (Jaksha et al. 1978; Jaksha and Locke 1978) should be consulted for this information.

In the Socorro area of the Rio Grande Rift, detailed studies of microearthquakes indicate no seismic activity below a depth of 13 km (Sanford, Olsen, Jaksha 1979). Similar studies by ASL and LASL in the Rio Grande Rift north of the Socorro indicate most activity is occurring in the upper crust (i.e., at depths of less than 20 km). Detailed microearthquake surveys have not been made in other physiographic provinces within the state such as the Colorado Plateau or the High Plains.

Magnitudes

The magnitudes listed in Table 3 are local magnitudes (M_L) calculated by New Mexico Tech. Because Wood-Anderson instruments located at NMT and ASL seldom recorded regional quakes, it was necessary to calculate the Wood-Anderson amplitudes from records produced by higher magnification instruments, such as those employed by the World Wide Seismic Station Network (WWSSN). The parameters required for the calculation are the amplitude and dominant period of the largest oscillations on the seismogram (i.e., always the S phase for earthquakes in New Mexico) and the frequency response characteristics of the instrument. From this information, ground motion is calculated and then converted to a Wood-Anderson trace amplitude using a magnification of 2800.

All magnitudes calculated by NMT from seismograms at stations SNM, TUC, LUB, and Golden (GOL), Colorado were adjusted to agree with Richter local magnitudes calculated from WWSSN seismograms recorded at the ALQ station. To minimize differences between ALQ magnitudes and the other station magnitudes, negative station corrections ranging from 0.13 at SNM to 0.50 at LUB were applied. The data from 211 regional earthquakes recorded from 1962 through 1972 were used to establish the station corrections.

The same data set was used to calculate a correction for the standard $\log_{10} A_0$ versus distance table used to determine local magnitudes. As noted by Richter (1958), the standard table was designed for earthquakes in southern California and therefore it may not necessarily apply elsewhere. Without correction, local magnitudes of New Mexico earthquakes were found to be systematically shifted to larger values with increasing distance from the epicenters. Application of a correction of -0.0014 times the epicen-

tral distance in kilometers was found to remove any dependence of magnitude on distance. The physical meaning of the correction is that the seismic waves are less attenuated with distance in New Mexico than southern California.

The NMT magnitudes listed in Table 3 are generally the average of magnitudes calculated from records from more than one station or type of instrument. A comparison of 13 NMT and LASL magnitudes indicates the latter magnitudes are on the average about 0.5 unit higher. A similar comparison between 21 LASL and ASL magnitudes indicates no significant difference on the average. Therefore, in order to make the listing of New Mexico shocks after September 1973 roughly consistent with the previous 11 2/3 year period, two procedures were adopted: either 0.5 was subtracted from LASL or ASL magnitudes or a new magnitude was calculated by NMT.

The choice of ALQ station WWSSN seismograms as a standard for NMT magnitude calculations was primarily because of the station's quiet location and its nearness to the center of the area investigated. However, this station is known to record smaller ground vibrations than other stations at the same distance from a seismic disturbance (Jordan et al. 1965). This factor, in conjunction with the distance correction used by NMT probably explains the difference observed between NMT and LASL magnitudes. The procedure were by LASL to calculate magnitudes is described by Newton et al. (1976). The ASL uses basically the same procedure as LASL (Jaksha and Locke 1978).

Relation of Seismic Activity to Geology

General

Figure 2 is a plot of the earthquake locations listed in Table 3. The symbols used to mark epicenters are scaled to the magnitudes of the

Figure 2. Instrumental locations of earthquakes in New Mexico for the period 1962 through 1972.

earthquakes, with the exception of two epicenters in the northwestern corner of the state for which magnitudes are unknown.

An immediate observation from Figure 2 is that seismic activity was detected in all major physiographic provinces during the 1962 through 1977 period. Also, the intensity of seismic activity in all physiographic provinces was very nearly the same. This conclusion is not immediately obvious from an examination of Figure 2. However, the data set plotted is biased towards weak shocks along or bordering the Rio Grande Rift because of the distribution of seismic stations.

A study of the earthquakes for the period 1962 to 1972 indicates that a magnitude 4.5 shock is the strongest earthquake to expect in a 100-year period/100,000 km² in both the High Plains and the Rio Grande Rift/Southern Basin and Range Provinces (Sanford et al. 1976). The result is surprising in light of the geology and the distribution of felt earthquakes prior to 1962.

The Rio Grande Rift differs structurally from neighboring physiographic provinces in that it has numerous normal faults in Miocene or younger age. Fault scarps offsetting a Quaternary geomorphic surface have been identified at many locations along the rift (Chapin 1971; Sanford et al. 1972; Sanford et al. 1974). Some of these fault scarps, notably those along the eastern fronts of the Magdalena and San Andres mountains, have lengths and vertical offsets suggesting association with earthquakes comparable in strength to the Sonoran earthquake of 1887 (Aguilera 1920). This major earthquake (probable magnitude of about 7.8) produced 80 km of fault scarp (with a maximum displacement of about 8.5 m) extending southward from the United States-Mexico border at about 109°W longitude.

A possible explanation for the discrepancy between geologic evidence of major crustal movements along the rift and the relatively moderate seismicity is that crustal extension along this geologic feature is episodic (Richter 1958). Existence of significant seismic gaps along the Rio Grande Rift as well as a level of seismicity no greater than the Colorado Plateau or the High Plains suggests very little or no crustal spreading of the rift in recent years. Geodetic measurements near Socorro are in agreement with this tentative conclusion (Prescott et al. 1979).

Specific Areas

Eastern Plains. Seismic activity in the southeastern corner of New Mexico is occurring along the Central Basin Platform, a buried structure of Late Pennsylvania-Early Permian age. They are where seismic activity is occurring, have extensive production of oil and gas, and are undergoing massive injection of water for secondary recovery of oil. Therefore, the possibility exists that the activity in this region is being induced (Sanford and Topozada 1974).

In the northern part of the Eastern Plains, the seismic activity also appears to be associated with buried structures of Late Pennsylvania-Early Permian age. This is an area which has no oil or gas production. Because of this observation, it is also possible that the activity on the Central Basin Platform is natural.

Northwestern New Mexico. This quadrant of New Mexico has a surprising amount of seismic activity considering its location in a supposedly stable physiographic province -- the Colorado Plateau. An interesting feature of the seismicity of this region is a semi-circular belt of activity surrounding the structurally deepest section of the San Juan Basin.

Raton-Jemez-Mt. Taylor Volcanic Belt. Some activity in the northwestern quadrant of the state appears to be associated with a belt of diffuse seismic activity extending from the northeast corner of the state through the Jemez volcanic field to the vicinity of Mt. Taylor (Sanford et al. 1976). This NE-SW belt of seismic activity coincides with a similar NE-SW lineation of volcanic centers of Miocene and younger age.

Rio Grande Rift. Although less than expected, considerable earthquake activity is occurring along the Rio Grande Rift. Pockets of high seismicity at Socorro and west of Espanola may be associated with contemporaneous movement of magma in the crust (Sanford Olsen and Jaksha 1979). Occurrence in swarms and probable locations in the axial regions of the rift also suggest that many of the strong historical earthquakes were closely linked with injection of magma into the crust.

Tularosa Basin. A fairly large number of earthquakes have been located in the Tularosa Basin. But perhaps more interesting is an apparent alignment of epicenters along a northward extension of the axis of the Tularosa Basin (approximately along the 106° meridian). This belt of activity includes a zone of epicenters east and south of Estancia recently defined by Jaksha et al. (1978) and Jaksha and Locke (1978).

Southwestern New Mexico. Figure 2 shows a cluster of events following the trend of the Mogollon and Burro mountains. Most of the activity lies to the east and south of the 1938 swarm in that area.

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Chapter 4

Heat Flow Maps of New Mexico

Part 1

Mapping by Silica Heat Flow Interpretation Technique*

Introduction

The silica heat flow interpretation technique is based on the temperature dependence of quartz solubility in water (the silica geothermometer of Fournier and Row, 1966), and the empirical linear relation between temperatures based on the silica geothermometer and regional heat flow (Swanberg and Morgan 1978). The silica geothermometer can be expressed quantitatively according to the equation of Truesdell

$$T_{SiO_2} = \frac{1314}{5.205 \log_{10} SiO_2} + 273.15, \quad (1)$$

(1975) where T_{SiO_2} is the silica geotemperature in degrees Celsius and dissolved silica is expressed in parts per million. The linear relation between silica geotemperatures and regional heat flow can be expressed quantitatively according to the empirical equation of Swanberg and Morgan

$$T_{SiO_2} = mq + b, \quad (2)$$

(1978) where q is regional heat flow in mW/m^2 and m and b are constants determined to be $670^\circ C \ m^2/W$ and $13.2^\circ C$, respectively. The physical significance of " b " is the mean annual air temperature and the slope " m " is related to the minimum average depth to which groundwaters may circulate.

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This minimum depth is estimated to be between 1.4 and 2.0 km depending upon the rock type. A full description of Equations (1) and (2), the assumptions upon which they are based and the condition under which they may be applied are presented by Truesdell (1975) and by Swanberg and Morgan (1978, 1980).

Equation (2) was originally derived by averaging 2000 to 10,000 values of T_{SiO_2} for each tectonic province in the United States for which regional heat flow was well known (Swanberg and Morgan 1978). More recently, Swanberg and Morgan (1980) redeveloped Equation (2) by plotting average values of T_{SiO_2} against heat flow for $1^\circ \times 1^\circ$ blocks using only those blocks for which both T_{SiO_2} and heat flow were well defined. Heat flow was considered to be well defined if at least three points were available and the standard deviation was less than 20 percent of the mean. Values of T_{SiO_2} were considered to be well defined if at least 100 points were available and the standard deviation was less than 20°C . The second regression is not sufficiently different from the first to justify changing the values of the constants m and b , and the preferred regression is

$$T_{SiO_2} = mq + b,$$

where m is $670 \pm 67^\circ\text{Cm}^2/\text{W}$ and b is $13.2 \pm 5.1^\circ\text{C}$. This second regression permits the averaging of a manageable number of silica values (50 to 100) to estimate regional heat flow over a fairly small region ($1^\circ \times 1^\circ = \sim 10^4 \text{ km}^2$); moreover, it permits the assignment of error estimates to the resulting heat flow. Thus, heat flow can be determined to $\pm 7.5 + 0.067q \text{ mW/m}^2$ of whatever value would be obtained if three traditional heat flow determinations existed, and they were in good agreement. Over the range of typical heat flow values (40 to 120 mW/m^2), these errors correspond to

11.5 and 19.5 mW/m. This variation is about the same as typically observed among standard heat flow determinations covering a comparable area; thus, it appears that the silica heat flow method works as well as the traditional approach.

Results

Figure 1 shows the traditional heat flow values from New Mexico (Sass and Lachenbruch 1979), the distribution of silica data points, and the heat flow contours based on both sets of data. This map is generally similar to that of Reiter et al. (1975) (see Figure 2), although the present map has considerably more detail. Figure 1 also shows the Rio Grande Rift (lined pattern) and the high heat flow of the rift is quite apparent.

Conclusions

The silica heat flow method has been used to prepare a new heat flow map of New Mexico. This map is generally similar to existing maps except that the abundance of silica data has made it possible to locate more accurately the contours between widely scattered heat flow sites and also provide coverage in these areas where conventional data are lacking. On the basis of this new heat flow map, the following conclusions can be drawn.

1. A zone of high flow (> 2.5 HFU) trends north-south through central New Mexico and is associated with the Rio Grande Rift.
2. The largest area of very high regional heat flow (> 3.0 HFU) is the portion of the Rio Grande Rift in south central New Mexico. Geothermal areas such as the Valles Caldera are obvious exceptions to this generalization.

Figure 1. Heat flow in New Mexico (Swanberg, 1979).

Figure 2. Terrestrial heat flow along the Rio Grande Rift, New Mexico and southern Colorado (Reiter et al., 1975).

3. Heat flow values in the Colorado Plateau of northwest New Mexico are generally normal (~ 1.5 HFU), although portions of the plateau located along the Jemez Lineament may have higher heat flow.
4. Heat flow values in the Basin and Range of southwest New Mexico show considerable scatter but generally fall between 2 and 3 HFU.
5. The heat flow in eastern New Mexico is uniformly normal (< 1.5 HFU).

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Part 2

Preliminary Heat Flow Study and Geothermal Assessment of Dona Ana County, New Mexico*

To delineate potential areas of low temperature geothermal resources in Dona Ana County, a search was conducted throughout southcentral New Mexico for abandoned boreholes suitable for temperature logging. Approximately 60 wells were identified and logged (see Figure 1). Temperature gradients have been calculated and thermal conductivities estimated to determine regional and local heat flow values. The results are summarized in Table 1 and are shown in Figures 2 through 6.

Large differences in conductive heat flow values at different levels in the same boreholes (see Table 1), plus the non-linearity of the temperature profiles (see Figures 7 through 16), indicate that the near surface geothermal regime is greatly affected by groundwater movements which cause thermal masking. Thermal masking is groundwater circulating in high yield aquifers that sweeps away thermally heated water at a faster rate than it can be supplied from depth. These groundwater movements include the downward percolation of cold recharge water, interbasin drainage, lateral groundwater flow and ascending flows of warm or hot water driven by piezometric gradients and/or hydrothermal convection. Consequently, reliable local heat flow values are not therefore readily available. Furthermore, heat flow in southcentral New Mexico is very complex and a clear understanding of the regional tectonics and associated

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Figure 1. Location map for Doña Ana County wells (Lohse, 1980).

Figure 2. Locations and magnitudes of heat flow values from above the water table in Doña Ana County (Lohse, 1980).

Figure 3. Location of temperature-logged wells in the Las Alturas area (Lohse, 1980).

Figure 4. Heat flow values from above the water table in the Las Alturas area (Lohse, 1980). For comparison, only the upper 30 to 40 meters of the deeper holes were used.

Figure 5. Locations of temperature-logged wells in the Santa Teresa area (Lohse, 1980).

Figure 6. Heat flow values from above the water table in the Santa Teresa area (Lohse, 1980).

Table 1. Temperature gradients and estimated heat flow values (Lohse, 1980).

Name	Long.	Lat.	Elev. (m)	D.I. (m)	T*** (°C/km)	Kest.*	H.F.**
Hole-1	107°00.1'	31°53.3'	1233	10-95	40.6±4.2	1.9	77±8
				95-130	24.4±0.6	3.2	78±2
Hole-2	107°00.1'	31°53.8'	1235	10-90	44.2±2.2	1.9	84±4
Hole-3	107°01.5'	31°57.0'	1254	10-30	38.6±5.2	1.9	73±10
Hole-4	107°00.3'	31°54.5'	1235	30-100	35.1±0.5	1.9	67±1
				110-130	17.4±0.5	3.2	56±2
Hole-5	107°00.8'	31°54.8'	1248	15-60	41.7±0.6	1.9	79±1
DA-1	106°39.0'	32°17.4'	1380	20-50	56.2±2.8	2.1	118±6
				55-65	35.0±2.9	3.5	53±10
DA-2	106°55.4'	31°55.4'	1227	20-25	54.0±0.1	3.2	173±10
DA-3	106°54.3'	32°00.8'	1257	10-85	88.2±15.3	1.9	168±29
				85-115	76.1±3.8	1.9	145±7
DA-4	106°52.2'	31°57.8'	1253	30-110	70.2±0.6	1.9	133±1
DA-5	106°52.9'	32°13.5'	1263	35-100	17.6±0.6	1.7	30±1
DA-6	106°51.8'	32°08.2'	1257	25-105	38.4±0.4	1.7	65±1
				110-260	15.9±0.3	2.5	40±1
NMSU-3	106°43.9'	32°17.3'	1218	10-100	51.7±0.7	2.1	109±1
				105-150	20.6±4.0	3.5	72±14
NMSU-4	106°43.0'	32°16.2'	1230	10-30	415.8±9.4	2.1	873±20
NMSU-5	106°42.9'	32°15.9'	1236	10-30	386.8±6.1	2.1	812±13
NMSU-6	106°44.1'	32°16.7'	1206	10-30	87.6±2.6	2.1	184±5
NMSU-7	106°43.6'	32°16.8'	1224	10-30	320.2±12.3	2.1	672±26
NMSU-8	106°43.2'	32°17.0'	1248	10-30	445.8±14.8	2.1	936±31
NMSU-9	106°42.8'	32°17.2'	1266	10-30	433.0±5.6	2.1	909±12
NMSU-10	106°43.6'	32°17.0'	1242	10-70	221.2±10.7	2.1	465±22
				85-145	112.9±3.0	3.5	395±11
DT-1	106°43.1'	32°17.0'	1254	10-75	302.9±8.3	2.1	636±17
				80-300	74.1±29.8	3.5	259±104
DT-2	106°43.5'	32°16.9'	1230	10-75	256.8±11.5	2.1	539±24
				80-360	7.7±2.5	3.5	27±9
LC-2	106°43.1'	32°21.2'	1310	10-125	220	2.1	462
				125-265	142	3.5	498
Hacienda	106°41.5'	32°22.8'	1344	10-130	39.6±0.6	2.1	83±1
Acres				135-340	40.3±0.0	3.5	141±0
J. ABRAM	106°45.0'	32°19.7'	1230	35-130	1.8±0.2	3.5	6±1
ST-3	106°40.7'	31°50.7'	1227	15-95	85.1±2.9	1.7	145±5
				100-180	37.9±1.3	2.5	95±3
ST-5	106°41.6'	31°51.2'	1226	15-95	45.0±3.7	1.7	77±6
				100-175	37.2±1.4	2.5	93±4
ST-6	106°41.4'	31°51.8'	1232	15-105	62.7±1.2	1.7	107±2
				105-175	29.5±1.4	2.5	74±4
ST-7	106°38.4'	31°51.4'	1140	10-20	164.0±31.2	1.7	279±53
				20-70	42.5±1.3	2.5	106±3
ST-9	106°41.4'	31°50.7'	1223	15-90	68.7±1.8	1.7	117±3
				95-170	32.5±3.0	2.5	81±8

* Units are $W m^{-1} K^{-1}$; uncertainty is about 20%. ($1 W m^{-1} K^{-1} = 2.39 mcal cm^{-1} sec^{-1} K^{-1}$)

** Units are $mW m^{-2}$; errors presented are due entirely to errors in temperature gradients and do not include errors in thermal conductivity values ($41.8 mW m^{-2} = 1 HFU = 1 \mu cal cm^{-2} sec^{-1}$)

*** Errors are standard deviations of least squares fit to temperature data over specified depth intervals.

†† Thermal conductivities from Reiter, M., Shearer, C., and Edwards, C.L., Geothermal anomalies along the Rio Grande rift in New Mexico, Geology, 6, 85-88, 1978.

Table 1. (continued).

Name	Long.	Lat.	Elev. (m)	D.I. (m)	T*** (°C/km)	Kest.*	H.F.**
DA-7	107°01.8'	31°59.4'	1263	50-105	71.2±1.1	1.9	135±2
DA-8	106°49.8'	31°58.2'	1250	50-110	75.8±0.4	1.9	144±1
DA-9	106°56.9'	31°57.7'	1250	20-90	66.7±0.5	1.9	127±1
DA-10	107°05.3'	32°25.4'	1434	40-230	50.0±0.2	1.9	95±0
DA-11	107°14.8'	32°24.4'	1446	235-250	44.1±2.8	3.2	141±9
				10-30	74.0±3.4	1.9	141±6
				30-85	49.7±0.4	1.9	94±1
				90-115	36.6±2.6	3.2	117±8
DA-12	107°17.7'	32°22.7'	1398	10-60	84.5±6.9	1.9	161±13
				60-80	12.6±1.8	3.2	40±6
				10-50	102.8±6.5	1.9	195±12
DA-13	107°14.1'	32°32.9'	1491		neg. gradient		
DA-14	106°48.1'	32°17.9'	1169				
DA-15	107°12.3'	32°14.4'	1290	10-30	102.2±11.2	1.9	194±21
				30-70	46.2±1.1	3.2	148±4
DA-16	107°17.5'	32°36.2'	1353	10-25	86.4±11.6	1.9	164±22
DA-17	107°09.8'	32°35.7'	1410	10-15	42.0±0.1	3.2	134±0
DA-18	107°00.9'	32°36.1'	1200	10-15	60.0±0.1	3.2	192±0
SD-1	106°59.9'	32°37.6'	1260	10-55	277.1±18.5	1.9	526±35
				80-175	70.4±0.6	3.2	225±2
SD-2	106°58.9'	32°36.5'	1373	10-150	213.6±1.1	3.15 ⁺⁺	673±3
SD-3	106°59.1'	32°36.3'	1388	10-150	219.8±0.9	2.93 ⁺⁺	643±3
LA-1	106°43.6'	43°15.8'	1200	10-50	51.2±2.3	2.1	108±5
				50-85	26.1±1.4	3.5	91±5
LA-2	106°43.2'	32°16.1'	1226	10-65	322.3±7.7	2.1	677±16
				65-75	105.9±1.3	3.5	371±5
LA-3	106°43.1'	32°15.9'	1218	10-60	297.9±3.3	2.1	626±7
				60-95	129.8±4.6	3.5	454±16
KMSU-1	106°45.0'	32°16.6'	1176		neg. gradient		
NMSU-2	106°45.3'	32°16.2'	1178		neg. gradient

Figure 7. Temperature-depth profiles for wells logged near the East Potrillo Mountain area (Lohse, 1980).

Figure 8. Temperature-depth profiles for wells logged in the Kilbourne Hole area (Lohse, 1980).

Figure 9. Temperature-depth profiles for wells logged in and around the Sierra de las Uvas area (Lohse, 1980).

Figure 10. Temperature-depth profiles for wells logged in the northern part of the Mesilla Bolson and the San Diego Mountain area (Lohse, 1980).

Figure 11. Temperature-depth profiles for wells originally logged in the Las Alturas area (Lohse, 1980).

Figure 12. Temperature-depth profiles of deep wells logged in the Las Alturas area (Lohse, 1980).

Figure 13. Temperature-depth profiles of shallow wells and upper portion (0-35 m) of deep wells logged in the Las Alturas area (Lohse, 1980).

Figure 14. Temperature-depth profiles for wells logged in the Santa Teresa area in the Rio Grande Valley (Lohse, 1980).

Figure 15. Temperature-depth profiles for wells with temperatures greater than well ST-29 in the Santa Teresa area on the mesa (Lohse).

Figure 16. Temperature-depth profiles for wells with temperatures less than well ST-29 logged in the Santa Teresa area on the mesa (Lohse, 1980).

Figure 17. Histogram of heat flow values from above the water table in Dona Ana County.

thermal regime, regional hydrology, and geological and geophysical data and their implications is necessary in order to interpret the heat flow data. Nevertheless, a few general observations can be made. A histogram (see Figure 17) of the local heat flow values shows that the regional heat flow is approximately 100 to 150 mW/m^2 (2.4 to 3.6 HFU*). Superimposed upon this regional value are abnormally low heat flow values in the Mesilla Bolson and possibly in the southern Jornada del Muerto areas, and abnormally high values at San Diego Mountain and the Las Alturas geothermal anomaly. The values in the northcentral part of the Mesilla Bolson average about 45 mW/m^2 (1.1 HFU). The values at San Diego Mountain and Las Alturas are greater than 400 mW/m^2 ($\sim$ 10.0 HFU). Hydrothermal activity in the area appears to be fault controlled.

In summary, the high regional heat flow observed throughout the Rio Grande Rift is also observed in Dona Ana County. Superimposed upon this high regional flux are several areas of abnormally high heat flow representing potentially producible geothermal areas (San Diego Mountain, Las Alturas, and Kilbourne Hole) and several areas where groundwater disturbance has led to lower than normal measured heat flow (Mesilla Bolson and the southern part of Jornada Del Muerto).

*1 HFU = 1 $\mu\text{cal cm}^{-2} \text{ sec}^{-1}$

Reference

Lohse, Richard L., 1980, Heat flow study of Dona Ana County, Southern Rio Grande Rift, New Mexico, unpublished M.S. thesis, New Mexico State University, Las Cruces, New Mexico.

Chapter 5

Thermal Gradients*

The following is a summary of wells logged, their locations and temperature gradients. Also included are the raw data. An interpretive report on these data is presented in Chapter 4, Part 2. Field data were obtained by Dr. Paul Morgan, Richard Lohse, Dr. Chandler Swanberg, Rick Kelley, Shari Alexander, Richard Montman, Justine Gilkey, Ruth Keeling, Sandra Rybarczyk, Dannie Stokes and Jose Fernandez.

*The primary compiler for Chapter 5 is Richard L. Lohse, Geothermal Field Engineer, New Mexico Energy Institute, New Mexico State University. Field data were obtained by Dr. Paul Morgan, Associate Professor of Physics and Earth Sciences, New Mexico State University, Richard L. Lohse, and Dr. Chandler A. Swanberg, Associate Professor of Physics and Earth Sciences, New Mexico State University.

Table 1. Actual temperature-depth data gathered from existing bore-holes.

HOLE-1 285.1W.7.13		HOLE-2 285.1W.6.333		HOLE-3 275.2W.23.223	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	21.16	10.0	20.82	10.0	19.56
15.0	20.94	15.0	20.74	15.0	19.64
20.0	20.92	20.0	20.85	20.0	19.98
25.0	20.97	25.0	20.87	30.0	20.29
30.0	20.99	30.0	21.08		
35.0	21.17	35.0	21.15		
40.0	21.28	40.0	21.27		
45.0	21.38	45.0	21.75		
50.0	21.43	50.0	22.08		
55.0	21.69	55.0	22.33		
60.0	21.89	60.0	22.50		
65.0	22.11	65.0	22.83		
70.0	22.36	70.0	22.96		
75.0	22.84	75.0	23.31		
80.0	23.28	80.0	23.43		
85.0	23.57	85.0	23.53		
90.0	23.89	90.0	24.25		
95.0	24.79	95.0	24.31		
100.0	24.90				
105.0	25.01				
110.0	25.17				
115.0	25.31				
120.0	25.41				
125.0	25.51				
130.0	25.63				

Table 1. (continued).

HOLE-4 28S.2W.1.21		HOLE-5 27S.2W.36.34		DA-1 23S.3E.21.31	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	21.71	10.0	20.58	5.0	20.08
15.0	21.77	15.0	20.67	10.0	22.52
20.0	21.87	20.0	20.85	15.0	21.69
25.0	22.08	25.0	21.02	20.0	21.13
30.0	22.39	30.0	21.25	25.0	21.46
35.0	22.60	35.0	21.45	30.0	21.77
40.0	22.74	40.0	21.64	35.0	22.08
45.0	22.92	45.0	21.91	40.0	22.32
50.0	23.13	50.0	22.11	45.0	22.45
55.0	23.30	55.0	22.32	50.0	22.91
60.0	23.41			55.0	22.86
65.0	23.57			60.0	22.96
70.0	23.75			65.0	23.01
75.0	23.92				
80.0	24.10				
85.0	24.26				
90.0	24.52				
95.0	24.73				
100.0	24.91				
110.0	25.79				
115.0	25.87				
120.0	25.96				
125.0	26.06				
130.0	26.13				

Table 1. (continued).

DA-2 27S.1W.26.43		DA-3 26S.1W.25.41		DA-4 27S.1E.17.22	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	19.54	5.0	22.25	5.0	21.59
10.0	18.66	10.0	20.75	10.0	21.00
15.0	19.48	15.0	20.92	15.0	21.13
20.0	19.99	20.0	20.63	20.0	21.23
25.0	20.26	25.0	20.69	25.0	21.40
		30.0	20.71	30.0	21.65
		35.0	20.79	35.0	21.98
		40.0	20.96	40.0	22.35
		45.0	21.39	45.0	22.71
		50.0	21.83	50.0	23.02
		55.0	22.13	55.0	23.52
		60.0	22.75	60.0	23.75
		65.0	23.19	65.0	24.12
		70.0	23.64	70.0	24.50
		75.0	23.51	75.0	24.87
		80.0	27.54	80.0	25.17
		85.0	29.09	85.0	25.58
		90.0	29.28	90.0	25.87
		95.0	29.79	95.0	26.33
		100.0	30.23	100.0	26.61
		105.0	30.62	105.0	26.90
		110.0	31.03	110.0	27.15
		115.0	31.20		

Table 1. (continued).

DA-5	24S.1E.7.444	DA-6	25S.1E.16.111
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	19.73	5.0	19.73
10.0	19.71	10.0	20.51
15.0	19.93	15.0	20.80
20.0	19.97	20.0	20.63
25.0	20.15	25.0	20.72
30.0	30.36	30.0	20.90
35.0	20.33	35.0	21.06
40.0	20.40	40.0	21.23
45.0	20.46	45.0	21.40
50.0	20.52	50.0	21.59
55.0	20.55	55.0	21.80
60.0	20.64	60.0	22.01
65.0	20.79	65.0	22.19
70.0	20.83	70.0	22.47
75.0	20.95	75.0	22.66
80.0	21.04	80.0	22.82
85.0	21.14	85.0	22.99
90.0	21.24	90.0	23.19
95.0	21.36	95.0	23.34
100.0	21.46	100.0	23.55
105.0	21.52	105.0	23.72
110.0	21.55	110.0	23.88
		115.0	23.96
		120.0	24.04
		125.0	24.12
		130.0	24.21
		135.0	24.32
		140.0	24.40
		145.0	24.50
		150.0	24.63
		155.0	24.79
		160.0	24.87
		165.0	24.91
		170.0	25.00
		175.0	25.12
		180.0	25.15
		185.0	25.20
		190.0	25.23
		195.0	25.27
		200.0	25.36
		205.0	25.50
		210.0	25.59
		215.0	25.73
		220.0	25.84
		225.0	25.85
		230.0	25.83
		235.0	25.93
		240.0	26.00
		245.0	26.03
		250.0	26.12
		255.0	26.16
		260.0	26.17

Table 1. (continued).

DA-7	27S.2W.2.14	DA-8	27S.1E.11.314	DA-9	27S.1W.15.13
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	20.68	5.0	14.14	5.0	21.84
10.0	20.81	10.0	21.21	10.0	21.19
15.0	21.63	15.0	22.61	15.0	21.97
20.0	21.47	20.0	21.82	20.0	22.21
25.0	21.65	25.0	22.24	25.0	22.54
30.0	21.87	30.0	22.63	30.0	22.84
35.0	22.07	35.0	22.99	35.0	23.16
40.0	22.33	40.0	23.22	40.0	23.43
45.0	22.62	45.0	23.47	45.0	23.83
50.0	22.82	50.0	23.73	50.0	24.22
55.0	23.13	55.0	24.09	55.0	24.53
60.0	23.45	60.0	24.43	60.0	24.87
65.0	23.80	65.0	24.90	65.0	25.27
70.0	24.08	70.0	25.25	70.0	25.56
75.0	24.41	75.0	25.60	75.0	25.85
80.0	24.83	80.0	26.02	80.0	26.21
85.0	25.24	85.0	26.33	85.0	26.51
90.0	25.52	90.0	26.76	90.0	26.79
95.0	25.93	95.0	27.15		
100.0	26.34	100.0	27.48		
105.0	26.73	105.0	27.89		
110.0	27.04	110.0	28.26		
		115.0	28.55		

Table 1. (continued).

DA-10 225.2W.6.411		DA-11 225.4W.10.232	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	18.46	5.0	17.22
10.0	18.53	10.0	18.28
15.0	18.73	15.0	18.74
20.0	19.22	20.0	19.13
25.0	19.63	25.0	19.44
30.0	19.94	30.0	19.78
35.0	20.10	35.0	20.06
40.0	20.43	40.0	20.31
45.0	20.66	45.0	20.57
50.0	20.87	50.0	20.84
55.0	21.11	55.0	21.09
60.0	21.31	60.0	21.33
65.0	21.54	65.0	21.57
70.0	21.76	70.0	21.79
75.0	22.00	75.0	22.04
80.0	22.24	80.0	22.28
85.0	22.47	85.0	22.55
90.0	22.72	90.0	22.87
95.0	22.95	95.0	23.00
100.0	23.22	100.0	23.21
105.0	23.46	105.0	23.44
110.0	23.72	110.0	23.66
115.0	23.96	115.0	23.71
120.0	24.22		
125.0	24.46		
130.0	24.70		
135.0	24.96		
140.0	25.21		
145.0	25.47		
150.0	25.73		
155.0	25.98		
160.0	26.25		
165.0	26.50		
170.0	26.76		
175.0	27.03		
180.0	27.27		
185.0	27.52		
190.0	27.78		
195.0	28.02		
200.0	28.27		
205.0	28.52		
210.0	28.80		
215.0	29.06		
220.0	29.31		
225.0	29.62		
230.0	29.97		
235.0	30.11		
240.0	30.31		
245.0	30.54		
250.0	30.77		

Table 1. (continued).

DA-12	22S.4W.19.323	DA-13	20S.4W.22.444	DA-14	23S.1E.13.411
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	17.44	5.0	15.43	5.0	20.60
10.0	18.54	10.0	15.67	10.0	20.77
15.0	19.28	15.0	15.79	15.0	20.77
20.0	19.79	20.0	16.28	20.0	20.56
25.0	20.21	25.0	17.12	25.0	20.29
30.0	20.47	30.0	17.20	30.0	19.95
35.0	20.67	35.0	17.72	35.0	19.61
40.0	20.98	40.0	18.21	40.0	19.28
45.0	21.26	45.0	19.04	45.0	18.99
50.0	21.69	50.0	19.83	50.0	18.72
55.0	22.39			55.0	18.49
60.0	23.69			60.0	18.30
65.0	23.76			65.0	18.16
70.0	23.78			70.0	18.05
75.0	23.91			75.0	17.95
80.0	23.93			80.0	17.88
				85.0	17.83
				90.0	17.80
				95.0	17.79
				100.0	17.80

Table 1. (continued).

DA-15	24S.4W.12.222	DA-16	20S.4W.6.232	DA-17	20S.30.4.321
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	17.88	5.0	16.83	5.0	18.31
10.0	19.10	10.0	17.88	10.0	19.10
15.0	19.80	15.0	18.52	15.0	19.31
20.0	20.50	20.0	18.91		
25.0	20.79	25.0	19.19		
30.0	21.16				
35.0	21.31				
40.0	21.51				
45.0	21.76				
50.0	21.92				
55.0	22.21				
60.0	22.50				
65.0	22.75				
70.0	22.94				

Table 1. (continued).

DA-18		SD-1	
205.2W.1.322		19S.2W.25.412	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	17.25	10.0	14.15
10.0	17.33	15.0	16.84
15.0	17.63	20.0	18.67
		25.0	20.57
		30.0	21.66
		35.0	22.58
		40.0	23.38
		45.0	23.73
		50.0	26.38
		55.0	28.31
		60.0	28.57
		65.0	28.77
		70.0	28.89
		75.0	28.95
		80.0	29.16
		85.0	29.68
		90.0	30.12
		95.0	30.56
		100.0	30.77
		105.0	31.01
		110.0	31.52
		115.0	31.87
		120.0	32.19
		125.0	32.48
		130.0	32.82
		135.0	33.19
		140.0	33.53
		145.0	33.98
		150.0	34.29
		155.0	34.60
		160.0	34.96
		165.0	35.34
		170.0	35.68
		175.0	36.00

Table 1. (continued).

SD-2 195.1W.31.432		SD-3 195.1W.31.344		LA-1 235.2E.34.322	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	22.07	10.0	22.04	10.0	21.56
15.0	23.41	15.0	23.01	15.0	21.78
20.0	24.39	20.0	24.14	20.0	21.99
25.0	25.44	25.0	25.38	25.0	22.23
30.0	26.86	30.0	26.26	30.0	22.44
35.0	27.76	35.0	28.35	35.0	22.66
40.0	28.85	40.0	28.50	40.0	22.93
45.0	29.87	45.0	29.51	45.0	23.30
50.0	30.87	50.0	30.65	50.0	23.68
55.0	31.86	55.0	31.72	55.0	23.76
60.0	33.92	60.0	32.83	60.0	23.89
65.0	34.35	65.0	33.95	65.0	24.05
70.0	35.46	70.0	35.11	70.0	24.21
75.0	36.55	75.0	36.21	75.0	24.36
80.0	37.67	80.0	37.28	80.0	24.49
85.0	38.73	85.0	38.42	85.0	24.50
90.0	39.88	90.0	39.41		
95.0	40.82	95.0	40.57		
100.0	41.86	100.0	41.79		
105.0	42.91	105.0	42.82		
110.0	43.93	110.0	44.35		
115.0	44.94	115.0	44.92		
120.0	45.98	120.0	46.06		
125.0	47.12	125.0	47.22		
130.0	48.13	130.0	48.46		
135.0	49.15	135.0	49.55		
140.0	50.07	140.0	50.59		
145.0	51.03	145.0	51.74		
150.0	51.82	150.0	52.75		

Table 1. (continued).

LA-2	23S.2E.34.224	LA-3	23S.2E.34.244	NMSU-1	23S.2E.28.313
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	22.62	10.0	22.81	5.0	24.01
15.0	24.31	15.0	24.14	10.0	22.53
20.0	26.37	20.0	25.52	15.0	22.19
25.0	28.23	25.0	27.23	20.0	22.06
30.0	30.12	30.0	28.32	25.0	21.26
35.0	31.78	35.0	30.03	30.0	21.18
40.0	33.37	40.0	31.29	35.0	21.26
45.0	50.0	45.0	32.99	40.0	20.74
50.0	36.27	50.0	34.78	45.0	20.53
55.0	37.67	55.0	36.06	50.0	20.35
60.0	38.95	60.0	37.59	55.0	20.21
65.0	40.26	65.0	38.57	60.0	20.10
70.0	40.80	70.0	39.09	65.0	20.02
75.0	41.32	75.0	39.81	70.0	20.01
80.0	41.42	80.0	40.51	75.0	20.08
		85.0	41.12	80.0	20.13
		90.0	41.64	85.0	20.21
		95.0	42.07	90.0	20.32
		100.0	42.18	95.0	20.35

Table 1. (continued).

NMSU-2	23S.2E.32.213	NMSU-3	23S.2E.22.331	NMSU-4	23S.2E.35.111
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	22.36	5.0	20.24	5.0	23.49
10.0	10.53	10.0	21.11	10.0	23.80
15.0	18.61	15.0	21.35	15.0	25.98
20.0	18.24	20.0	21.65	20.0	28.27
25.0	18.26	25.0	21.92	25.0	30.15
		30.0	22.19	30.0	32.11
		35.0	22.41		
		40.0	22.84		
		45.0	23.06		
		50.0	23.29		
		55.0	23.53		
		60.0	23.80		
		65.0	24.18		
		70.0	24.26		
		75.0	24.34		
		80.0	24.84		
		85.0	25.00		
		90.0	25.24		
		95.0	25.52		
		100.0	25.83		
		105.0	26.85		
		110.0	27.43		
		115.0	27.83		
		120.0	27.77		
		125.0	27.78		
		130.0	27.81		
		135.0	27.87		
		140.0	27.94		
		145.0	28.83		
		150.0	28.09		

Table 1. (continued).

NMSU-5		NMSU-6		NMSU-7	
23S.2E.35.134		23S.2E.28.422		23S.2E.27.144	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	23.36	5.0	21.75	5.0	23.40
10.0	24.62	10.0	20.64	10.0	24.07
15.0	26.48	15.0	21.08	15.0	25.28
20.0	28.63	20.0	21.58	20.0	27.07
25.0	30.44	25.0	22.00	25.0	28.89
30.0	32.31	30.0	22.37	30.0	30.27

Table 1. (continued).

NMSU-8	23S.2E.8.223	NMSU-9	23S.2E.26.114	NMSU-10	23S.2E.27.124
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	23.75	5.0	24.18	5.0	22.87
10.0	25.19	10.0	24.80	10.0	24.99
15.0	27.66	15.0	26.86	15.0	26.72
20.0	30.08	20.0	29.15	20.0	28.60
25.0	32.19	25.0	31.37	25.0	30.29
30.0	34.07	30.0	33.37	30.0	31.46
				35.0	32.59
				40.0	33.62
				45.0	34.57
				50.0	35.56
				55.0	36.42
				60.0	37.17
				65.0	38.02
				70.0	38.65
				75.0	38.70
				80.0	39.37
				85.0	40.80
				90.0	41.67
				95.0	42.39
				100.0	42.96
				105.0	43.58
				110.0	44.22
				115.0	44.76
				120.0	45.29
				125.0	45.83
				130.0	46.40
				135.0	46.87
				140.0	47.27
				145.0	47.62

Table 1. (continued).

DT-1 23S.2E.27.224		DT-1 (con't)		DT-1 (con't)	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	23.22	150.0	57.43	191.0	59.48
10.0	26.23	155.0	57.76	192.0	59.50
15.0	28.58	160.0	58.09	193.0	59.43
20.0	30.82	165.0	58.33	194.0	59.57
25.0	32.76	166.0	58.37	195.0	59.61
30.0	34.43	167.0	58.49	196.0	59.64
35.0	35.79	168.0	58.49	197.0	59.83
40.0	37.20	169.0	58.55	198.0	59.70
45.0	38.59	170.0	58.59	199.0	59.73
50.0	39.97	171.0	58.83	200.0	59.79
55.0	41.51	172.0	58.83	201.0	59.82
60.0	42.52	173.0	58.73	202.0	59.85
65.0	44.85	174.0	58.79	203.0	59.85
70.0	45.37	175.0	58.82	204.0	59.92
75.0	46.76	176.0	58.87	205.0	59.98
80.0	48.04	177.0	58.91	206.0	60.00
85.0	49.88	178.0	58.93	207.0	60.03
90.0	50.13	179.0	58.99	208.0	60.08
95.0	50.97	180.0	59.04	209.0	60.09
100.0	51.93	181.0	59.07	210.0	60.13
105.0	52.73	182.0	59.11	211.0	60.17
110.0	53.41	183.0	59.15	212.0	60.20
115.0	54.04	184.0	59.19	213.0	60.24
120.0	54.57	185.0	59.24	214.0	60.28
125.0	55.17	186.0	59.27	215.0	60.30
130.0	55.71	187.0	59.31	216.0	60.34
135.0	56.21	188.0	59.38	217.0	60.37
140.0	56.72	189.0	59.39	218.0	60.39
145.0	57.10	190.0	59.43	219.0	60.43

Table 1. (continued).

DT-1 (con't)		DT-1 (con't)		DT-1 (con't)	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
220.0	60.45	249.0	61.29	278.0	62.00
221.0	60.48	250.0	61.32	279.0	62.02
222.0	60.58	251.0	61.34	280.0	62.04
223.0	60.54	252.0	61.37	281.0	62.02
224.0	60.57	253.0	61.39	282.0	62.06
225.0	60.60	254.0	61.42	283.0	62.10
226.0	60.63	255.0	61.45	284.0	62.12
227.0	60.65	256.0	61.47	285.0	61.13
228.0	60.68	257.0	61.48	286.0	62.16
229.0	60.70	258.0	61.51	287.0	62.17
230.0	60.74	259.0	61.54	288.0	62.20
231.0	60.77	260.0	61.56	289.0	62.21
232.0	60.79	261.0	61.59	290.0	62.24
233.0	60.83	262.0	61.61	291.0	62.25
234.0	60.86	263.0	61.63	292.0	62.28
235.0	60.89	264.0	61.65	293.0	62.29
236.0	60.92	265.0	61.68	294.0	62.30
237.0	60.96	266.0	61.71	295.0	62.33
238.0	60.98	267.0	61.73	296.0	62.34
239.0	61.02	268.0		297.0	62.37
240.0	61.05	269.0	61.79	298.0	62.38
241.0	61.08	270.0	61.81	299.0	62.41
242.0	61.11	271.0	61.84	300.0	62.43
243.0	61.14	272.0	61.88		
244.0	61.18	273.0	61.89		
245.0	61.19	274.0	61.90		
246.0	61.21	275.0	61.93		
247.0	61.24	276.0	61.96		
248.0	61.28	277.0	61.98		

Table 1. (continued).

DT-2 23S, 2E, 27, 233		DT-2 (con't)	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	21.70	245.0	49.23
10.0	24.91	250.0	49.19
15.0	26.88	255.0	49.16
20.0	28.99	260.0	49.13
25.0	30.53	265.0	49.11
30.0	32.75	270.0	49.10
35.0	34.03	275.0	49.10
40.0	34.94	280.0	49.09
45.0	36.20	285.0	49.09
50.0	57.33	290.0	49.08
55.0	38.34	295.0	49.08
60.0	39.39	300.0	49.08
65.0	40.37	305.0	49.08
70.0	41.25	310.0	49.08
75.0	42.20	315.0	49.08
80.0	42.93	320.0	49.09
85.0	43.66	325.0	49.10
90.0	44.51	330.0	49.12
95.0	45.13	335.0	49.16
100.0	45.73	340.0	49.19
105.0	46.49	345.0	49.26
110.0	47.18	350.0	49.33
115.0	47.64	355.0	49.47
120.0	48.25	360.0	49.61
125.0	48.85		
130.0	49.51		
135.0	50.01		
140.0	50.37		
145.0	50.63		
150.0	50.79		
155.0	50.85		
160.0	50.83		
165.0	50.75		
170.0	50.68		
175.0	50.58		
180.0	50.45		
185.0	50.32		
190.0	50.19		
195.0	50.05		
200.0	49.94		
205.0	49.82		
210.0	49.71		
215.0	49.62		
220.0	49.53		
225.0	49.48		
230.0	49.39		
235.0	49.23		
240.0	49.27		

Table 1. (continued).

LC-2		22S.2E.34.244		HACIENDA ACRES		22S.2E.24.422	
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	20.30	5.0	21.11	5.0	21.11	5.0	21.11
10.0	22.70	10.0	19.95	10.0	19.95	10.0	19.95
15.0	23.70	15.0	20.30	15.0	20.30	15.0	20.30
20.0	24.90	20.0	20.57	20.0	20.57	20.0	20.57
25.0	26.60	25.0	20.80	25.0	20.80	25.0	20.80
30.0	28.30	30.0	21.06	30.0	21.06	30.0	21.06
35.0	30.10	35.0	21.73	35.0	21.73	35.0	21.73
40.0	31.90	40.0	21.53	40.0	21.53	40.0	21.53
45.0	33.70	45.0	21.79	45.0	21.79	45.0	21.79
50.0	34.40	50.0	21.98	50.0	21.98	50.0	21.98
55.0	35.30	55.0	22.18	55.0	22.18	55.0	22.18
60.0	36.20	60.0	22.37	60.0	22.37	60.0	22.37
65.0	37.10	65.0	22.55	65.0	22.55	65.0	22.55
70.0	37.80	70.0	22.73	70.0	22.73	70.0	22.73
75.0	38.70	75.0	22.92	75.0	22.92	75.0	22.92
80.0	39.70	80.0	23.10	80.0	23.10	80.0	23.10
85.0	40.60	85.0	23.27	85.0	23.27	85.0	23.27
90.0	41.60	90.0	23.46	90.0	23.46	90.0	23.46
95.0	42.30	95.0	23.62	95.0	23.62	95.0	23.62
100.0	43.00	100.0	23.79	100.0	23.79	100.0	23.79
105.0	44.10	105.0	23.98	105.0	23.98	105.0	23.98
110.0	44.90	110.0	24.18	110.0	24.18	110.0	24.18
115.0	45.90	115.0	24.37	115.0	24.37	115.0	24.37
120.0	46.90	120.0	24.54	120.0	24.54	120.0	24.54
125.0	48.00	125.0	24.73	125.0	24.73	125.0	24.73
130.0	48.90	130.0	24.91	130.0	24.91	130.0	24.91
135.0	49.40	135.0	25.12	135.0	25.12	135.0	25.12
140.0	50.20	140.0	25.31	140.0	25.31	140.0	25.31
145.0	50.90	145.0	25.51	145.0	25.51	145.0	25.51
150.0	51.60	150.0	25.72	150.0	25.72	150.0	25.72
155.0	52.50	155.0	25.92	155.0	25.92	155.0	25.92
160.0	53.40	160.0	26.13	160.0	26.13	160.0	26.13
165.0	54.20	165.0	26.33	165.0	26.33	165.0	26.33
170.0	54.90	170.0	26.52	170.0	26.52	170.0	26.52
175.0	55.40	175.0	26.72	175.0	26.72	175.0	26.72
180.0	56.60	180.0	26.92	180.0	26.92	180.0	26.92
185.0	57.10	185.0	27.13	185.0	27.13	185.0	27.13
190.0	57.80	190.0	27.33	190.0	27.33	190.0	27.33
195.0	58.30	195.0	27.55	195.0	27.55	195.0	27.55
200.0	59.20	200.0	27.74	200.0	27.74	200.0	27.74
205.0	59.70	205.0	27.93	205.0	27.93	205.0	27.93
210.0	60.40	210.0	28.14	210.0	28.14	210.0	28.14
215.0	61.00	215.0	28.33	215.0	28.33	215.0	28.33
220.0	61.50	220.0	28.53	220.0	28.53	220.0	28.53
225.0	62.00	225.0	28.72	225.0	28.72	225.0	28.72
230.0	62.80	230.0	28.92	230.0	28.92	230.0	28.92
235.0	63.70	235.0	29.13	235.0	29.13	235.0	29.13
240.0	64.50	240.0	29.32	240.0	29.32	240.0	29.32
245.0	65.10	245.0	29.52	245.0	29.52	245.0	29.52
250.0	65.40	250.0	29.72	250.0	29.72	250.0	29.72
255.0	66.30	255.0	29.93	255.0	29.93	255.0	29.93
260.0	67.10	260.0	30.14	260.0	30.14	260.0	30.14
265.0	67.90	265.0	30.34	265.0	30.34	265.0	30.34
		270.0	30.54	270.0	30.54	270.0	30.54
		275.0	30.73	275.0	30.73	275.0	30.73
		280.0	30.94	280.0	30.94	280.0	30.94
		285.0	31.13	285.0	31.13	285.0	31.13

Table 1. (continued).

HACIENDA ACRES (con't)		J. ABRAM	23S.2E.9.111
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
290.0	31.33	5.0	22.40
295.0	31.54	10.0	19.68
300.0	31.74	15.0	20.78
305.0	31.95	20.0	21.33
310.0	32.16	25.0	21.26
315.0	32.39	30.0	21.23
320.0	32.59	35.0	21.11
325.0	32.79	40.0	21.12
330.0	32.99	45.0	21.13
335.0	33.21	50.0	21.14
340.0	33.39	55.0	21.17
		60.0	21.19
		65.0	21.21
		70.0	21.22
		75.0	21.23
		80.0	21.24
		85.0	21.17
		90.0	21.17
		95.0	21.19
		100.0	21.20
		105.0	21.23
		110.0	21.24
		115.0	21.26
		120.0	21.30
		125.0	21.31
		130.0	21.33

Table 1. (continued).

ST-3	28S.3E.30.141	ST-5	28S.2E.24.342
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP °C)
25.0	35.00	10.0	21.95
10.0	19.33	15.0	22.17
15.0	19.45	20.0	22.28
20.0	19.69	25.0	22.34
25.0	19.99	30.0	22.34
30.0	20.23	35.0	22.39
35.0	20.51	40.0	22.46
40.0	20.83	45.0	22.61
45.0	20.95	50.0	22.79
50.0	20.51	55.0	22.96
55.0	22.15	60.0	23.14
60.0	22.47	65.0	23.46
65.0	23.00	70.0	23.84
70.0	23.73	75.0	24.29
75.0	24.05	80.0	24.66
80.0	24.54	85.0	25.06
85.0	24.96	90.0	25.39
90.0	25.52	95.0	25.71
95.0	26.14	100.0	26.43
100.0	26.55	105.0	26.52
105.0	26.68	110.0	26.70
110.0	26.81	115.0	26.86
115.0	26.95	120.0	27.02
120.0	27.09	125.0	27.20
125.0	27.25	130.0	27.34
130.0	27.37	135.0	27.47
135.0	27.56	140.0	27.54
140.0	27.70	145.0	27.71
145.0	27.86	150.0	28.00
150.0	28.10	160.0	28.27
155.0	28.41	165.0	28.58
160.0	28.65	170.0	28.82
165.0	28.89	175.0	29.03
170.0	29.15	180.0	29.16
175.0	29.33		29.17
180.0	29.48		

Table 1. (continued).

ST-6	28S.2E.24.213	ST-7	28S.3E.21.144	ST-9	28S.2E.25.23
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	20.48	10.0	22.79	5.0	21.81
15.0	20.57	15.0	23.34	10.0	21.21
20.0	20.85	20.0	24.43	15.0	20.85
25.0	21.27	25.0	24.67	20.0	21.16
30.0	21.81	30.0	24.97	25.0	21.44
35.0	22.09	35.0	25.26	30.0	21.64
40.0	22.61	40.0	25.42	35.0	21.90
45.0	22.47	45.0	25.57	40.0	22.14
50.0	22.99	50.0	25.69	45.0	22.61
55.0	23.17	55.0	25.93	50.0	22.84
60.0	23.46	60.0	26.24	55.0	23.20
65.0	23.68	65.0	26.45	60.0	23.54
70.0	24.07	70.0	26.60	65.0	23.92
75.0	24.33			70.0	24.31
80.0	24.70			75.0	24.77
85.0	25.04			80.0	25.17
90.0	25.35			85.0	25.58
95.0	25.69			90.0	26.05
100.0	26.03			95.0	26.33
105.0	26.52			100.0	26.41
110.0	26.64			105.0	26.54
115.0	26.78			110.0	26.66
120.0	26.93			115.0	26.80
125.0	27.08			120.0	26.90
130.0	27.21			125.0	26.94
135.0	27.37			130.0	26.97
140.0	27.50			135.0	26.98
145.0	27.53			140.0	27.06
150.0	27.57			145.0	27.32
155.0	27.71			150.0	27.76
160.0	28.00			155.0	28.11
165.0	28.28			160.0	28.48
170.0	28.54			165.0	28.67
175.0	28.71			170.0	28.84
180.0	28.75				

Table 1. (continued).

ST-10	28S.2E.36.142	ST-12	28S.3E.17.211	ST-14	28S.2E.33.34-
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	20.46	10.0	23.33	20.0	22.45
15.0	20.69	15.0	23.80	25.0	22.43
20.0	20.96	20.0	24.04	30.0	22.57
25.0	21.24	25.0	24.93	35.0	22.70
30.0	21.48	30.0	25.18	40.0	22.89
35.0	21.70	35.0	25.44	45.0	23.03
40.0	21.88	40.0	25.53	50.0	23.25
45.0	22.18	45.0	25.77	55.0	23.48
50.0	22.41	50.0	25.87	60.0	23.74
55.0	22.70	55.0	25.92	65.0	24.01
60.0	23.31	60.0	25.93	70.0	24.29
65.0	23.47	65.0	25.94	75.0	24.57
70.0	23.94			80.0	25.21
75.0	24.24			85.0	25.60
80.0	24.77			90.0	25.82
85.0	25.17			95.0	25.94
90.0	25.48			100.0	27.01
95.0	25.90			105.0	27.08
100.0	26.34			110.0	27.23
105.0	26.85			115.0	27.41
110.0	26.97			120.0	27.60
115.0	27.11			125.0	27.74
120.0	27.23			130.0	27.88
125.0	27.33			135.0	28.02
130.0	27.40			140.0	28.16
135.0	27.47			145.0	28.30
140.0	27.59			150.0	28.35
145.0	27.80			155.0	28.38
150.0	28.13			160.0	28.43
155.0	28.47			165.0	28.44
160.0	28.79			170.0	28.45
165.0	29.02				
170.0	29.14				

Table 1. (continued).

ST-15	28S.3E.17.442	ST-21	28S.3E.27.434	ST-23	28S.3E.34.112
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	22.49	10.0	22.04	5.0	23.06
15.0	23.07	15.0	22.90	10.0	23.84
20.0	23.69	20.0	23.81	15.0	23.33
25.0	24.95	25.9	24.98	20.0	24.23
30.0	25.11	30.0	25.22	25.0	25.04
35.0	25.27	35.0	25.43	30.0	25.18
40.0	25.48	40.0	25.65	35.0	25.37
45.0	25.56	45.0	25.83	40.0	25.56
50.0	25.59	50.0	26.06	45.0	25.79
55.0	25.62	55.0	26.17	50.0	25.98
60.0	25.69	60.0	26.21	55.0	26.09
65.0	25.63	65.0	26.29	60.0	26.16
70.0	25.72	70.0	26.60	65.0	26.26
75.0	25.88	75.0	26.85	70.0	26.56
80.0	26.06	80.0	27.03	75.0	26.80
		85.0	27.34	80.0	26.93
				85.0	27.24

Table 1. (continued).

ST-25	28S.2E.13.332	ST-26	28S.2E.14.421
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
5.0	20.29	30.0	65.00
10.0	21.44	10.0	19.24
15.0	21.33	15.0	19.74
20.0	21.45	20.0	20.01
25.0	21.61	25.0	20.46
30.0	21.80	30.0	21.06
35.0	22.00	35.0	21.28
40.0	22.29	40.0	21.58
45.0	22.68	45.0	21.91
50.0	23.01	50.0	22.16
55.0	23.28	55.0	22.49
60.0	23.65	60.0	22.81
65.0	23.99	65.0	23.14
70.0	24.36	70.0	23.57
75.0	24.76	75.0	24.01
80.0	25.32	80.0	24.49
85.0	25.73	85.0	25.08
90.0	26.13	90.0	25.48
95.0	26.55	95.0	25.81
100.0	26.91	100.0	26.38
105.0	27.32	105.0	27.67
110.0	27.48	110.0	27.82
115.0	27.67	115.0	27.99
120.0	27.85	120.0	28.20
125.0	28.03	125.0	28.37
130.0	28.23	130.0	28.56
135.0	28.36	135.0	28.71
140.0	28.42	140.0	28.90
145.0	28.50		
150.0	28.61		
155.0	28.74		
160.0	28.99		
165.0	29.26		
170.0	29.45		
175.0	29.66		

Table 1. (continued).

ST-27	28S.3E.19.133	ST-28	28S.3E.20.123	ST-29	28S.2E.24.444
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	20.72	10.0	21.71	10.0	21.22
15.0	20.96	15.0	22.25	15.0	21.34
20.0	21.32	20.0	22.78	20.0	21.80
25.0	21.54	25.0	23.47	25.0	21.87
30.0	21.80	30.0	24.12	30.0	22.31
35.0	22.07	35.0	24.59	35.0	22.78
40.0	22.35	40.0	25.52	40.0	23.05
45.0	22.79	45.0	25.63	45.0	23.31
50.0	23.24	50.0	25.82	50.0	23.58
55.0	23.52	55.0	26.04	55.0	23.94
60.0	23.86	60.0	26.24	60.0	24.23
65.0	24.21	65.0	26.40	65.0	24.59
70.0	24.56	70.0	26.44	70.0	25.07
75.0	24.89	75.0	26.45	75.0	25.38
80.0	25.26	80.0	26.46	80.0	25.70
85.0	25.63	85.0	26.47	85.0	26.01
90.0	25.98	90.0	26.46	90.0	26.29
95.0	26.35			95.0	26.77
100.0	26.64			100.0	26.89
105.0	26.77			105.0	27.02
110.0	26.90			110.0	27.17
115.0	27.00			115.0	27.33
120.0	27.15			120.0	27.54
125.0	27.29			125.0	27.71
130.0	27.38			130.0	27.89
135.0	27.43			135.0	28.07
140.0	27.47			140.0	28.24
145.0	27.57			145.0	28.33
150.0	27.71			150.0	28.41
155.0	27.90			155.0	28.44
160.0	28.02			160.0	28.45

Table 1. (continued).

ST-30	285.3E.30.414	ST-31	285.3E.29.334
DEPTH (M)	TEMP (°C)	DEPTH (M)	TEMP (°C)
10.0	19.98	10.0	21.51
15.0	19.22	15.0	21.58
20.0	19.74	20.0	21.61
25.0	19.96	25.0	21.76
30.0	20.43	30.0	22.13
35.0	20.39	35.0	22.52
40.0	21.17	40.0	22.78
45.0	21.71	45.0	23.13
50.0	22.29	50.0	23.53
55.0	22.94	55.0	23.87
60.0	23.20	60.0	24.14
65.0	23.82	65.0	24.58
70.0	23.96	70.0	25.07
75.0	24.23	75.0	25.41
80.0	24.63	80.0	25.78
85.0	25.16	85.0	26.09
90.0	25.66	90.0	26.46
95.0	26.27	95.0	26.75
100.0	26.75	100.0	27.17
105.0	26.87	105.0	27.23
110.0	27.04	110.0	27.28
115.0	27.19	115.0	27.53
120.0	27.41	120.0	27.65
125.0	27.57	125.0	27.66
130.0	27.75	130.0	27.67
135.0	27.85	135.0	27.67
140.0	27.87		
145.0	27.89		
150.0	28.07		
155.0	28.39		
160.0	28.63		
165.0	28.89		
170.0	29.34		

Table 2. Depth intervals and temperature gradients calculated from raw data given in Table 1.

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
Hole-1	106°59'	31°53'	1233	50- 70	46
				70- 80	92
				80- 90	61
				95-105	22
				110-130	22
Hole-2	106°59'	31°54'	1235	45- 75	50
				75- 85	22
Hole-3	107°01'	31°57'	1254	20- 30	31
Hole-4	106°59'	31°54'	1235	30- 55	36
				60- 85	34
				90-100	39
				110-130	17
Hole-5	107°00'	31°55'	1248	15- 40	39
				45- 60	40
DA-2	106°55'	31°56'	1227	10- 20	133
				20- 25	54
DA-3	106°54'	32°01'	1257	40- 50	87
				60- 70	88
				95-110	82

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
DA-4	106°52'	31°58'	1263	20- 35	40
				35- 45	55
				50- 65	65
				65- 75	61
				75- 85	83
				90-105	81
DA-8	106°49'	31°58'	1250	20- 35	78
				35- 50	49
				50- 60	70
				65- 75	70
				80- 95	75
				100-110	78
DA-9	106°56'	31°58'	1250	20- 35	63
				45- 60	66
				65- 75	58
				80- 90	58
DA-5	106°52'	32°14'	1263	35- 50	13
				55- 65	24
				70-100	21
DA-6	106°51'	32°08'	1257	25- 45	34
				45- 65	50
				70-105	36

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient (°C/km)
				110-150	19
				155-170	13
				175-200	9
DA-10	107°05'	32°25'	1434	40- 95	46
				95-135	50
				135-210	51
				210-220	51
				220-230	66
				235-250	44
DA-11	107°14'	32°25'	1446	20- 30	65
				35- 85	49
				95-110	44
DA-12	107°18'	32°22'	1398	5- 60	91
				60- 80	13
DA-13	107°14'	32°33'	1491	30- 40	101
				40- 50	162
DA-15	107°12'	32°14'	1290	10- 20	140
				20- 30	66
				35- 55	45
				60- 70	44

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient (°C/km)
SD-1	107°00'	32°38'	1260	15- 25	373
				30- 40	164
				55- 80	32
				80- 95	93
				95-105	45
				110-140	66
				145-175	68
DA-1	106°39'	32°18'	1380	20- 35	63
				55- 65	15
LA-1	106°44'	32°16'	1200	10- 35	44
				40- 50	75
				55- 80	30
LA-2	106°43'	32°16'	1226	10- 30	378
				30- 40	325
				45- 55	281
				55- 65	259
				65- 75	106
LA-3	106°43'	32°16'	1218	10- 20	271
				25- 40	278
				40- 50	349
				50- 60	281
				60- 80	146
				85- 95	95

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
NMSU-1	106°45'	32°17'	1176		Neg. Grad.
NMSU-2	106°45'	32°16'	1178		Neg. Grad.
NMSU-3	106°44'	32°18'	1218	10- 35 40- 60 85-100	53 48 55
				110-120 130-145	32 15
NMSU-4	106°43'	32°16'	1230	10- 30	416
NMSU-5	106°43'	32°16'	1236	10- 30	387
NMSU-6	106°44'	32°17'	1206	10- 30	88
NMSU-7	106°44'	32°17'	1224	10- 30	320
NMSU-8	106°43'	32°17'	1248	10- 30	446
NMSU-9	106°43'	32°17'	1266	10- 30	433
DT-1	106°43'	32°17'	1254	10- 30	411
				30- 50 60- 75	277 275

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
				80- 90	209
				90-100	180
				105-115	132
				115-125	112
				125-140	103
				140-160	68
				160-185	45
				185-210	36
				210-240	30
				240-270	25
				270-300	20
DT-2	106 $^{\circ}$ 44'	32 $^{\circ}$ 17'	1230	10- 30	393
				30- 50	227
				50- 65	203
				65- 75	183
				75- 85	166
				85-100	125
				100-110	145
				115-130	124
DA-14	106 $^{\circ}$ 47'	32 $^{\circ}$ 18'	1169		Neg. Grad.
J. Abram	106 $^{\circ}$ 45'	32 $^{\circ}$ 20'	1230	35- 80	3
				85-130	4
Hacienda Acres	106 $^{\circ}$ 41'	32 $^{\circ}$ 23'	1344	20- 45	49
				45-130	36
				130-310	40
				315-340	40

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
ST-3	106°41'	31°51'	1227	20- 40	56
				40- 55	120
				75- 85	91
				85- 95	118
				100-130	28
ST-5	106°41'	31°51'	1226	40- 60	34
				65- 85	80
				85- 95	65
				105-125	34
ST-6	106°41'	31°52'	1232	50- 65	47
				80-100	66
				105-140	28
ST-7	106°38'	31°51'	1140	10- 20	164
				20- 35	56
ST-9	106°41'	31°51'	1223	15- 25	59
				30- 40	50
				50- 70	73
				70- 90	86
				95-120	24
ST-10	106°42'	31°50'	1233	65- 90	82
				90-100	86
				105-125	24

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient (°C/km)
ST-12	106°40'	31°53'	1149	10- 25	101
				25-35	51
ST-14	106°43'	31°51'	1233	45- 55	45
				55- 75	55
				105-120 120-145	35 28
ST-15	106°39'	31°52'	1146	10-25	160
				25- 35	32
ST-21	106°37'	31°50'	1143	10- 25	195
				25- 50	43
ST-23	106°37'	31°50'	1137	15- 25	171
				30- 50	40
ST-25	106°42'	31°52'	1233	35- 50	68
				55- 75	73
				80-105	80
				105-135	36

Table 2. (continued).

Name	Long.	Lat.	Elev. (m)	Depth Interval (m)	Temperature Gradient ($^{\circ}\text{C}/\text{km}$)
ST-26	106°42'	31°52'	1233	35- 45	63
				50- 65	65
				65- 80	90
				85-100	81
				105-140	36
ST-27	106°41'	31°52'	1226	20- 40	52
				40- 50	89
				55- 95	71
				100-130	25
ST-28	106°40'	31°52'	1191	10- 20	107
				20- 30	134
				45- 65	39
ST-29	106°41'	31°51'	1224	35- 50	53
				55- 65	65
				70- 90	61
				95-115	28
				120-140	35
ST-30	106°40'	31°50'	1224	35- 50	113
				80- 90	103
				100-115	30
				120-130	34
ST-31	106°40'	31°50'	1218	25- 35	76
				40- 55	73
				60- 70	93
				70- 95	68
				100-110	11

Chapter 6

Volcano-Tectonics

Part 1

Quaternary and Late Pliocene Geology*

This chapter presents the data collected on late Pliocene and Quaternary tectonic activity and vulcanism and is broken into two parts.

Part 1 contains a set of references from which data on Quaternary and late Pliocene geology were taken. Figure 1 shows post Tertiary anticlinal and synclinal warps, faults which cut late Pliocene and/or Quaternary surfaces and Quaternary volcanic rocks less than four million years old.

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Figure 1. Locations of Quaternary and late Pliocene tectonic activity and volcanism.

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Part 2

Quaternary and Late Pliocene Age Dates, Mining Prospects and Water Isotope Analyses*

Part 2 contains a set of references from which Quaternary and late Pliocene age dates and mining prospects were taken and are presented in Figure 1. The age dates were determined from samples taken from volcanic rocks. The mining prospects show areas known to be rich in certain minerals. Also shown in Figure 1 are the results of water isotope analyses.

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SOURCES OF AGE DATES AND MINING
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Chapter 7

Available Geoelectrical Studies*

The accompanying reference list and map index of available geoelectrical studies in New Mexico are divided into seven categories: EL - electrical logging, EM - electromagnetic, ER - electrical resistivity, GD - geomagnetic depth sounding - magnetic variation, IP - induced polarization, MT - magnetotelluric and telluric, and SP - self-potential surveys. Listing within each category is chronological to facilitate updating. All known and available references to these surveys in New Mexico, including contracts and grants currently in progress, have been compiled; however, omissions have probably occurred and current information is sought. Continual updating of the geoelectrical activities in New Mexico is of special interest. Notable omissions in the available information are private industry investigations such as induced polarization measurements in sulfide exploration and electrical logs obtained during petroleum exploration. Many other geoelectrical surveys obtained during geothermal prospecting have not been included because of their proprietary nature.

Although most locations have been confirmed on the index map (see Figure 1) by recourse to the original reference, this is not the case with less accessible reports and publications. In these cases, a secondary reference or location by title was used. Figure 1 is a reproduction of the index map which was prepared as an overlay to the Quaternary and Late

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Figure 1. Reproduction of the index map for geoelectrical studies.

Pliocene Geology map by Jonathan F. Callender and William R. Seager which is one of the companion maps in the State of New Mexico Geothermal Geoscience Map Series 1979.

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Chapter 8

Geothermal Hydrology*

As part of the DOE sponsored Low Temperature Geothermal Evaluation Program in New Mexico, an evaluation of hydrologic characteristics of the low temperature geothermal sites was initiated during the latter part of the summer of 1978. The following material is based on two months of work done during August and September 1978:

1. Figures 1 through 8 show bottom-hole temperatures in deep wells in New Mexico. Most of these wells are oil and gas wells, but some water wells are also included. Most of the wells shown in Figures 7 and 8 (Grant and Dona Ana Counties) are water wells. Figure 1 shows temperatures and depths of deep wells scattered throughout the state. Separate maps have been prepared for counties for which there are a large number of data points. The counties represented in Figures 2 through 8 are San Juan, Rio Arriba, McKinley, Sandoval, Harding, Grant and Dona Ana, respectively.
2. On the basis of data shown in Figures 1 through 8, plus supplemental information previously reported by other workers, a map showing 46 anomalous low temperature geothermal areas in New Mexico was prepared and is shown in Figure 9. The 46 areas are numbered from north to south along lines running west to east.

*The principal author of Chapter 8 is Dr. Lokesh Chaturvedi, Associate Professor of Earth Sciences and Civil Engineering, New Mexico State University.

Figure 1. Measured bottom-hole temperatures in oil and gas wells in New Mexico.

Figure 2. Measured bottom-hole temperatures in oil and gas wells in San Juan County, New Mexico.

Figure 3. Measured bottom-hole temperatures in oil and gas wells in Rio Arriba County, New Mexico.

Figure 4. Measured bottom-hole temperatures in oil and gas wells in McKinley County, New Mexico.

Figure 5. Measured bottom-hole temperatures in oil and gas wells in Sandoyal County, New Mexico.

Figure 6. Measured bottom-hole temperatures in oil and gas wells in Harding County, New Mexico.

Figure 8. Measured bottom-hole temperatures in oil, gas and water wells and surface temperatures of hot springs in Dona Ana County, New Mexico.

Figure 9. Anomalous areas of New Mexico.

Table 1. Areas favorable for development of low-temperature (< 90°C) geothermal resources in New Mexico.

Area No.	Area Name	Wells Considered No.	Range of Depth (m)	Range of Temp. (°C)	Thermal Springs No. & Range of Temp. (°C)	Representative Temperature Gradients (°C km ⁻¹)	Measured or Estimated Reservoir Temp. (°C)	Depth (m)	Total Dissolved Solids (mg l ⁻¹)	Remarks	Approx. Location		Reference
											Lat	Long	
1	Huasteco Mesa (a 25 mi. S. of Farmington)	11(4)	117-2055	27-72		64	>49	648			36 30	106 17	Chaturvedi
2	Jicarilla Apache Reservation	35(6)	666-4115	41-90		71	>76	763			36 20	107 23	
3	Puerto Chimulita	1	904	85		60	>55	904			36 30	106 15	
4	Cjo Caliente	3	13-27	15-56	5 32-45		130	C.G.	2500		36 20	106 00	Switzer
5	Mazzy's Hot Spring				1 34-38		125	C.G.	500	30 gpm	36 30	105 40	
6	Ponce de Leon				1 31-35		105	C.G.		240 gpm	36 20	105 40	
7	Taratshi	2	244-762	39			>39			Harrison formation deeper well flows 800 gpm	35 55	104 35	
8	Red Mountain Ranch	1	293	32		75	>32	293			35 55	108 00	Chaturvedi
9	Little Blue Mesa	2	304-656	32-48		70	>48	626			35 55	107 25	
10	Valles Caldera	12	710-2125	120-240	5 32-70	very high	240		5000		35 40	106 30	Switzer
11	Crownpoint	1	614	42		52	>42	614			35 40	105 10	
12	Hinsdale	4(2)	497-904	41-56		59	>56	904			35 40	107 50	Chaturvedi
13	Montezuma				26 31-50		130	C.G.	530	325 gpm	35 40	105 20	Switzer
14	Canada Marcelina	1	639	43		52	>43	639			35 35	108 00	Chaturvedi
15	White Mesa	1	271	28			>28	271			35 35	107 30	
16	Guadalupe Area	1	7	35			170	C.G.			35 30	107 15	Switzer
17	San Ysidro	2	167-		3 25-45		100	C.G.			35 35	106 50	
18	Fort Wingate	1	593	61			>61	593			35 30	109 35	
19	Prewitt Area	1	7	46			150	C.G.			35 25	105 25	
20	Jemez Reservoir						150	C.G.			35 25	104 35	
21	Closson	7	7	61			61				35 15	107 20	
22	North of Socorro			41			150	C.G.			34 20	106 50	
23	L. San Augustin Plains			35			35				34 00	109 05	
24	Socorro	1	81	33	3 35		35		230	105 for Socorro gallery	34 05	107 00	Switzer
25	San Francisco Hot Springs			1 37			40		209	6.9 gpm	33 50	105 50	
26	Frisborn Canyon Spring			1 33			33		150	9.4 gpm	33 45	109 00	
27	Lower Frisco			11 35-49			150	C.G.	650	50 gpm	33 15	102 50	

Table 1. (continued).

Area Name	Hills Considered		Thermal Springs		Representative Temperature Gradients (°C km ⁻¹)	Measured or Estimated Reservoir Temp. Depth (m)	Total Dissolved Solids (mg l ⁻¹)	Remarks	Approx. Location		Referrer
	No.	Range of Depth (m)	No.	Range of Temp. (°C)					Lat	Long	
28 The Meadows			4	27-34		34	150		33 20	104 20	Swanberg
29 Gila Hot Spring			5	36-46		66	450	460 gpm	33 10	102 10	"
30 T or C			3	40-43		100 C.G.	2500		33 10	102 15	"
31 Turkey Creek Hot Spring			7	74		74			33 05	103 30	Swanberg
32 Cliff Area	2	11-81	1	75		35	91	500	35 50	100 35	Swanberg
33 Huebner H.S.			21	34-82		40	250		32 45	107 50	"
34 Derry Springs			1	34		100 C.G.	1000		32 50	107 15	Swanberg/Swanberg
35 San Diego Mtn.		var.				125 C.G.			32 40	107 00	Swanberg
36 Gorton Hill	1	301	34			45	361	9000	32 46	106 10	Swanberg
37 North of Lordsburg	4	25-147	27-35			35	147		32 30	108 55	Chaturvedi
38 Raymond H. S.			1	55		55	380		32 25	105 00	Swanberg
39 Patton H. S.	3	3-10	26-69			130 C.G.	3500		32 30	106 55	Swanberg/Swanberg
40 Lightning Rock			99			170 C.G.	1500		32 10	108 50	Swanberg
41 Lordsburg			33			150 C.G.			32 15	108 30	Swanberg
42 Las Alturas	8	90-240	25-607			120 C.G.	1600		32 15	106 45	Chaturvedi/Swanberg
43 Mesquite-Berido	2	153-219	31-35			120 C.G.	1000		32 10	106 40	Chaturvedi/Swanberg
44 Southern Tularosa Basin	1	7	71			150 C.G.			32 05	106 05	Swanberg
45 Milbourne Hole	1	2239	45			155 C.G.		500 gpm from (190-205 m) at 45°C	31 55	106 55	Swanberg
46 Columbus Area			31			155 C.G.			31 50	107 30	Swanberg

NOTE: C.G. = Chemical Geothermometer by Swanberg

The particular numbering system was used simply to make it easy to locate an area. Table 1 provides a brief description of each area. Appendix A provides a brief geohydrological description of each area. Included in these 46 areas are eight KGRAs, most of which are both high and low temperature resource areas. The KGRAs are identified by asterisks on the map as well as in Table 1. The area names are given on the basis of the some well known names such as Radium Springs, or on the basis of nearest town, community, reservation, ranch, or canyon.

More explanation is needed with regard to information included in Table 1 as follows:

a. Area Numbers

Increasing numbers are given along west to east lines starting from the northwest corner of the state down to the southeast corner. The numbers bear no significance.

b. Wells Considered

Beneath the column entitled "Wells Considered" is a subtitle designated as "No." If there are two numbers (e.g., 11(4)), then 11 equals the number of wells in the area and (4) equals the number of wells showing anomalous thermal gradients. An anomalous thermal gradient is defined as follows:

$$T > A + 4.0 + 1.5 (\text{normal gradient}) Z$$

where A = mean atmospheric temperature which is 50°F for New Mexico, normal gradient = 1.5°F per 100 feet for northwest New Mexico, and 1.8°F per 100 feet for southwest New Mexico, and Z = depth of recorded temperature in feet. Entries

under the columns "Range of depth" and "Range of temperature" are based on all wells recorded. For reservoir temperature and gradient estimation, only the wells shallower than 1070 meters (3500 feet) have been considered.

c. Representative Temperature Gradients (Approximate)

In a given area, the gradient was established by averaging temperatures in anomalous wells between 305 meters and 1070 meters deep, according to the following equation:

$$\text{Gradient} = \frac{T-A}{Z}.$$

It was experienced that using well temperature data less than 305 meters gave misleading results for the gradient.

d. Reservoir Temperature

Chaturvedi data: The reservoir temperature is the highest temperature at depth less than 1070 meters.

Swanberg data: Base temperatures were estimated by Swanberg using geochemical geothermometry where applicable. These are identified with the letters C.G. in the adjacent column. Where depth is also indicated, the temperature is an actually recorded water temperature

Summers data: Most of the data are actual measured temperatures. If the letters C.G. appear for depth, the entry is a geochemical geothermometer temperature estimated by Swanberg.

e. Total Dissolved Solids (TDS)

Where specific conductance was known, the TDS value was taken as the product of 0.65 and the specific conductance in mmhos. If the TDS data for a specific geothermal area

have not been reported, an average from surrounding springs and/or wells was computed.

f. Blank Spaces in Table 1

These cases indicate situations where data were not available or not enough information was available to base a conclusion.

3. Figure 10 shows the 46 geothermal anomalous areas with information on the geological formations which most likely act as the geothermal aquifers, superimposed on the map. The legend for the map is given on the page immediately following Figure 10.
4. The appendix contains brief geohydrological information on each of the 46 areas.
5. Since the work started near the end of the 1978 irrigation season, it was not possible to carry out a large number of pumping tests. However, preliminary results based on some successful tests conducted in the Animas Valley, the Mesilla Valley, and the Truth or Consequences area show the following results:
 - a. Animas Valley - Transmissibility of the shallow geothermal aquifer in Section 7, T.25S, R.19W is at least 15,500 gpd/ft*. It is most likely higher than this, but a more powerful pump is needed to conduct the pumping test satisfactorily. The farmer whose wells were used for this test is going to install a new pump and then more reliable information should be obtainable.

*Transmissibility data are given in the units of gallons/day per foot of screen (gpd/ft).

Legend
 Δ Water well
 ○ Thermal spring
 • Oil or gas well
 ● KGRA

Figure 10. Anomalous areas of New Mexico with geological formations which most likely act as geothermal aquifers.

LEGEND FOR FIGURE 10

Quaternary	Q	Alluvium, bolson deposits, dune sands
	Qv	Bandelier Tuffs and associated rocks
	QTb	Basalts, basaltic andesites
Tertiary	Tv	Volcanics, mainly rhyolitic and andesitic
	Ti	Intrusive rocks
	Tsj	Sandstones and shales of San Jose formation
	Tks	Lower Tertiary sediments of San Juan Basin (primarily sandstones and siltstones)
Cretaceous	Ku	Upper cretaceous sandstones and shales (principally Ojo Alamo sandstone)
	Kmv	Sandstones, limestones, and shales of Mesa Verde Group
	Kdm	Dakota Sandstone and Mancos shale on the flanks of the Zuni uplift, and west of the Nacimiento fault
Jurassic	J	Jurassic Morrison formation sediments (primarily sandstone and shales)
Triassic	Tr	Triassic sedimentary rocks exposed adjacent to Nacimiento fault (San Ysidro, No. 17).
Permian	Pz	Paleozoic limestones and shales
	P	Permian sedimentary formations (sandstones, limestones, shales) near Montezuma and in the Southern Sacramento Mountains
Precambrian	FP	Limestones and dolomites of Magdalena Group
	pE	Precambrian igneous rocks of granite composition

- b. Las Alturas - The shallow geothermal aquifer which has been tapped by a number of wells in the Las Alturas area appears to have a rather low transmissibility value of approximately 5000 to 8000 gpd/ft.
 - c. Truth or Consequences - Geothermal hydrology conditions in the Truth or Consequences area appear more favorable than almost any other area in the state, but they are complex and difficult to summarize.
6. During the short time available, it was not possible to carry out field work in the northern and northwestern part of the state other than for data collection at the Oil Conservation Commission and the State Engineer's offices in Santa Fe and Farmington.

APPENDIX

Brief Hydrogeological Description of Low Temperature Geothermal Areas in New Mexico (See Figures 9, 10 and Table 1)

- 1) Moncisco Mesa - thermal waters in deep wells in lower Tertiary sediments.
- 2) Jicarilla Apache Reservation - thermal waters in deep wells in sandstone and shales of the San Jose Formation.
- 3) Puerto Chiquita - one well in lower Tertiary sediments.
- 4) Ojo Caliente - the springs discharge through fractures in a metarhyolite of Precambrian age. The fractures consist primarily of vertical joints striking N 10° E, N 35° W and N 60° E. The metarhyolite is crisscrossed by numerous pegmatite dikes. Hot water also exists in an alluvial aquifer downslope from the bedrock.
- 5) Mamby's Hot Spring - the spring is located about 10 feet above the low water state of the Rio Grande and at the base of a basalt cliff. The water discharges from fractures in the basalt and some seepage occurs from alluvium at and below river level.
- 6) Ponce de Leon - the springs discharge from fractures in a fault zone of Precambrian quartz monzonite (possibly quartz diorite). Near the springs the rock has zones of hydrothermal alteration.
- 7) Tohatchi - two wells which are in Morrison formation sandstones and silt-stones.
- 8) Red Mountain Ranch - one well in sandstones and limestones of Mesa Verde Group (aquifer probably in Morrison).
- 9) Little Blue Mesa - two wells located in upper Cretaceous sandstones and shales.
- 10) Valles Caldera - thermal water in wells and springs is associated with deep circulation and high heat flow in and near the Jemez Caldera. Most of the area is covered by Tertiary and Quaternary volcanics, the Bandelier tuff accounting for most of the latter. However, numerous small outcrops of Paleozoic limestones and sandstones occur in the area.
- 11) Crownpoint - three wells located in sandstones, limestones and shales of the Mesa Verde Group (Morrison).
- 12) Hospah - wells in sandstones, limestones, shales of Mesa Verde Group (Morrison).

- 13) Montezuma Hot Springs - the water discharges from fractures in Precambrian granite. Four sets of fractures are apparent in the granite, the most pronounced of which dips to the west 44° to 80° . About a mile east of the spring is a major fault, and several small faults occur in the immediate area of the spring. Pennsylvania age limestone and sandstones crop out on the slopes above the springs.
- 14) Canada Marcelina - one well in an area of upper and middle Cretaceous sandstones, limestone and shales (Morrison).
- 15) White Mesa - one well located in Dakota sandstone and Mancos shale.
- 16) Guadalupe area - one well in an area of middle and lower Cretaceous sandstones and shales, with possibly some limestones.
- 17) San Ysidro - thermal waters are associated with deep circulation in the Nacimiento reverse fault. However, the nature of the aquifers is not known.
- 18) Fort Wingate - a well on the Fort Wingate Army Depot was anomalous from 1284 to 1945 feet. Formations at this depth were the Meseta Blanca Member of the Yeso Formation and the Abo Formation.
- 19) Prewitt area - one well in Dakota sandstone and Mancos shales (possibly into Morrison).
- 20) Jemez Reservoir - occurs in a region of Santa Fe group sands and gravels overlain by Quaternary basalts.
- 21) Closson - well(s) in a region of Precambrian granite forming the core of the Zuni Uplift.
- 22) North of Socorro - well in an area of Santa Fe group sands and gravels and more recent river alluvium.
- 23) E. San Augustin Plains - well(s) in an area of Tertiary volcanics (Datil) which in part are overlain by Quaternary sediments (sands and gravels).
- 24) Socorro - the thermal area is about two miles north-south by one-half mile east-west, and is located in the Socorro Mountains about three miles west of Socorro. The thermal waters occur at three man-made tunnels (galleries), built to intercept the flow of springs, and at one well (Blue Canyon Well). The water originates from fractures in a volcanic breccia (possibly a lahar) which feeds the galleries. The well passed through 270 feet of welded rhyolite tuff (laharic) and bottomed in andesite.

- 25) San Francisco Hot Springs - the springs discharge from beneath a talus cover and eventually into the San Francisco River about 40 feet below. The bedrock is a unit of volcanic conglomerate within the Datil Formation. The talus is derived from volcanic rocks overlying the volcanic conglomerate.
- 26) Freiborn Canyon Spring - the water discharges from bedding planes in the volcanic conglomerate unit of the Datil Formation (Tertiary). The discharge area is very small and most of the water discharges into Freiborn Canyon immediately below the spring.
- 27) Lower Frisco - the springs discharge from alluvium and the Gila conglomerate immediately upstream from where the San Francisco River crosses a thick sequence basalt tertiary. Water discharges from the bank and is also believed to discharge from the river bottom. The greatest discharge is immediately upstream of the basalt (within 100 feet of the basalt).
- 28) The Meadows - discharge is from an area 200 feet wide by 750 feet long. The discharge area is in alluvium. Bedrock in the area is rhyolite (some of which is intrusive) and densely welded ash flow tuff near the Middle Fork of the Gila River.
- 29) Gila Hot Spring - the springs are on the north side of the Gila River and discharge from fractures in rhyolite from river level to 30 feet above it.
- 30) Truth or Consequences - the springs occur in Magdalena limestone and Santa Fe gravels, which partly bury the limestones. The formation is highly deformed, with two fault zones occurring in the immediate area: the east-west trending Mud Springs fault, and the north-south trending Hot Springs faults. Also the Magdalena limestone underlying most of the downtown area has been overturned. The water discharges from the underlying Magdalena limestone into the overlying gravels, then migrates toward the Rio Grande.
- 31) Turkey Creek Hot Spring - the springs are in an area of Tertiary volcanics (Datil).
- 32) Cliff area - both wells and springs exist in the area. The aquifer is reported to be Gila conglomerate. However, the aquifer may be Quaternary or terrace gravels overlying the Gila conglomerate.
- 33) Mimbres Hot Springs - about 30 springs are located in the Mimbres Hot Springs fault zone. The surface rock is Rubia Peak latite and Kneeling Nun tuff. The water discharges from rhyolite and rhyolite porphyry (actually a crystal lithic tuff) of the Kneeling Nun tuff.

- 34) Derry Springs - the water discharges through travertine spring deposits on the west side of the Derry fault block. The springs are in Santa Fe Formation alluvial material immediately below the limestone bluffs of the fault block.
- 35) San Diego Mountain - complex geology, high thermal gradient in a well.
- 36) Garton well - located on the edge of the White Sands National Monument. The top 780 feet is valley fill; the bottom 206 feet are sandstones, limestones and shales. The depth to the aquifer is not known.
- 37) North of Lordsburg - four wells are located in Quaternary alluvium.
- 38) Faywood Hot Springs - springs occur along a northwestward trending fault. The area is covered by gravels of Quaternary age, which overlay rhyolite (probably Kneeling Nun tuff). The rhyolite in turn overlays limestones of the Magdalena Group.
- 39) Radium Hot Springs - springs discharge water from Tertiary rhyolites. At least two small faults occur in the rhyolite near the springs.
- 40) Lightning Dock - Quaternary alluvium.
- 41) Lordsburg - Quaternary alluvium.
- 42) Las Alturas - the wells now in use are in Santa Fe Formation gravels. A wildcat oil well was drilled in 1948-1949 to 2573 feet, encountering Mississippian rocks. It was also reported to have encountered steam and hot water.
- 43) Mesquite - Berino - Quaternary alluvium.
- 44) Southern Tularosa Basin - Quaternary alluvium, probably underlain by Paleozoic limestones and shales.
- 45) Kilbourne Hole - located in a maar formed by steam explosion, probably caused by intruding molten material coming in contact with groundwater. The crater contains gravels with broken basalt encountered with depth.
- 46) Columbus Area - Quaternary alluvium.

SECTION II

RESERVOIR ASSESSMENT OF THE LAS ALTURAS

GEOHERMAL ANOMALY

Chapter 9

Borehole Temperature Studies of the Las Alturas Geothermal Anomaly, New Mexico*

Three phases of borehole temperature studies have been made relative to the Las Alturas geothermal anomaly in southern New Mexico: (1) logging of "free" holes; (2) shallow gradient study; and (3) analysis of data from two 300-m test wells. A maximum temperature of 62.5°C (145°F) has been measured at 300 m in one of the tests, and the data indicate that the source of the anomaly is a hydrothermal circulation system. A simple analysis of the temperature data indicate vertical water flow rates of the order of 1×10^{-9} m/s (~ 1 ft/yr). The borehole temperature data have provided valuable information for delineating, evaluating, and characterizing the nature of the source of the anomaly.

Introduction

Geophysical, engineering and economic studies all indicate that the Las Alturas geothermal anomaly, located to the east of New Mexico State University's main campus, is a potentially economic low temperature geothermal resource for direct heat applications at the New Mexico State University campus (Gunaji et al. 1978; Dicey and Morgan, unpublished). Borehole temperature studies have been made in and around the Las Alturas

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anomaly in three phases: (1) regional exploration comprising temperature measurements in "free" holes; (2) drilling and measurement of 30-m temperature-gradient holes over the anomaly prior to the siting of deep test wells; and (3) drilling and measurement of two 300-m test wells.

Regional Borehole Temperature Studies

There are numerous boreholes in the Las Cruces area drilled primarily for domestic water supply to depths of a few hundred meters. Eight abandoned water wells were available for temperature measurements in the immediate vicinity of Las Alturas; the locations for six of these (NMSU-1,-2,-3, LA-1, -2, -3) are shown in Figure 1. The remaining two wells in the area are located off the map; the J. Abrams well is located approximately two miles to the NNW, and DA-1 approximately six miles to the east. The temperature data from these eight wells are shown in Figure 2.

The temperature logs fall into three distinct categories: negative gradients, normal gradients, and high gradients. Three wells with negative gradients, NMSU-1, NMSU-2, and J. ABRAMS, are all located to the west of Interstate 25, which approximately divides the irrigated areas of the Rio Grande Valley to the west from the undeveloped areas of the mesa to the east. The data from these wells clearly indicate recharge of groundwater by downward water flow. Three wells east of Interstate 25, namely NMSU-3, LA-1, and DA-1 show reasonably uniform positive temperature gradients of the order of $40^{\circ}\text{C}/\text{km}$ ($2.2^{\circ}\text{F}/100$ feet) below a depth of 20 m. These gradients are typical of the gradients normally measured in sediments in the Rio Grande Rift. Two wells at Las Alturas—that is, LA-2 and LA-3, have dramatically higher gradients of about $300^{\circ}\text{C}/\text{km}$ ($16.5^{\circ}\text{F}/100$ feet) down to the water table at approximately 60 m, below which depth the gradients

Figure 1. Locations of water wells close to Las Alturas from which temperature-gradient data were obtained.

Figure 2. Temperature-depth profiles for wells in the Las Alturas geothermal anomaly.

systematically decrease. These two wells provided the first temperature measurements in the geothermal anomaly and yielded gradients below the water table which indicate that the anomaly is caused by a hydrothermal circulation system. In addition, these two wells provided valuable information for further temperature studies; that is, the high gradients above the water table are essentially established in LA-2 and LA-3 at a depth of 10 to 20 m, which indicates that 30 m is an adequate depth for additional temperature gradient boreholes.

Shallow Gradient Boreholes

A program of shallow temperature gradient boreholes was planned to confirm the extension of the Las Alturas geothermal anomaly beneath university land adjacent to Las Alturas, and to provide additional data for site selection for deeper tests. On the basis of the temperature results from LA-2 and LA-3, 30 m was chosen as the depth for the shallow gradient holes.

Two holes, NMSU-4 and NMSU-5, were initially drilled to the east of Las Alturas at the locations shown in Figure 3. The temperature data from these holes, shown in Figure 4, indicate that the anomaly increases to the east of Las Alturas. The measured gradients in NMSU-4 and NMSU-5 are $416^{\circ}\text{C}/\text{km}$ and $387^{\circ}\text{C}/\text{km}$ (22.8 feet and $21.2^{\circ}\text{F}/100$ feet), respectively. The anomaly is thereby confirmed to extend to the east beneath university-owned land.

Data from earlier electrical resistivity studies at Las Alturas (Smith 1977; Jiracek and Gerety 1978) suggest that the anomaly extends at least one mile to the north of NMSU-4. Based on the resistivity interpretation, the LA-2 and LA-3 borehole temperature data, and local

Figure 3. Locations of 30-m temperature gradient test wells.

Figure 4. Temperature-depth profile of boreholes NMSU-4 through NMSU-9.

geologic information, it is thought that the most likely origin for the anomaly is a hydrothermal circulation system controlled by a NNW trending fault. A profile of four boreholes, namely, NMSU-6, -7, -8, and -9 were therefore drilled on an ENE line to the north of the proven temperature anomaly to provide data for deeper test site selection. The locations of the holes are shown in Figure 3. Temperature data from these holes (see Figure 4) clearly define the western margin of the anomaly with gradients increasing to the east as follows: NMSU-6, $88^{\circ}\text{C}/\text{km}$ ($4.8^{\circ}\text{F}/100$ feet); NMSU-7, $320^{\circ}\text{C}/\text{km}$ ($17.6^{\circ}\text{F}/100$ feet); NMSU-8, $446^{\circ}\text{C}/\text{km}$ ($24.5^{\circ}\text{F}/100$ feet). The anomaly appears to peak before the eastern hole (NMSU-9) on the profile, where a gradient of $433^{\circ}\text{C}/\text{km}$ ($23.8^{\circ}\text{F}/100$ feet) was measured, although this conjecture is not absolutely defined. No additional gradient holes were drilled to the east in order to investigate this apparent phenomenon. A tentative interpretation of all the temperature data is that hot water rises along a NNW striking fault to a zone crossing between the two wells NMSU-8 and -9, and then diffuses laterally.

The 300-m Test Wells

Two 300-m test wells were drilled on university land adjacent to Las Alturas under the supervision of L. Chaturvedi of the Civil Engineering Department at NMSU. The wells were sited on the basis of the interpretation of the data from the shallow gradient hole profiles, at the locations shown in Figure 5, based on the following logic. The first test well, DT-1, was sited 100 m east (downdip on the assumed fault) of the apparent peak of the anomaly defined by the temperature gradient profiles. With this well it was hoped to intersect and stay in the anomaly source to total depth. The second well, DT-2, was drilled 0.4 miles west of DT-1

Figure 5. Locations of 300-m temperature test wells.

along the profile, between shallow wells NMSU-7 and NMSU-8. This site was selected so that if the interpretation of the source of the anomaly as a narrow fault-controlled zone of rising hot water was incorrect, this well would intersect a more laterally extensive source at a greater depth from DT-1, but at a closer distance to the potential user, the NMSU campus. If the narrow fault source interpretation were correct, however, DT-2 would provide information about the lateral flow from the system, and act as a site for a reinjection well, if required. Wells DT-1 and DT-2 were drilled in December 1978 and January 1979 and completed as temperature test wells at depths of 300m and 360 m, respectively, with two-inch water filled casing.

Temperature data from the two 300-m test wells are shown in Figure 6. The first well, DT-1, appears to have been drilled either into or very close to the source of the anomaly, and has a positive gradient to total depth, although the gradient decreases all the way down the hole, especially below the water table at approximately 80 m. A maximum temperature of 62.5°C (145°F) was recorded at 300 m, the base of the well. The second well, DT-2, reaches a maximum temperature of 50.8°C (123°F) at a depth of 160 m, at which point the gradient becomes negative, indicating a heating of the zone around 160 m by a lateral flow of hot water. Below 275 m, the gradient in DT-2 becomes positive again, with the temperature increasing to 49.6°C (121°F) at 360 m, the base of the well. These data clearly indicate the source of the anomaly to be in the vicinity of DT-1, with a lateral hydrothermal flow towards DT-2 to the west. The nature of the circulation to the east of DT-1 has not yet been determined.

The curvature in the geothermal gradient in DT-1 can be used to estimate the vertical component of water flow in strata penetrated by the well using the relationship

Figure 6. Temperature-depth data from 300-m test wells.

$$q = K \frac{dT}{dz} + \rho C v dT, \quad (1)$$

where q is the total vertical component of heat flow, K is the thermal conductivity of a zone, dT/dz is the temperature gradient in the zone, ρ and C are the density and specific heat of water, respectively, and v is the vertical component of water flow velocity, and dT is the temperature drop across the zone. By using temperature gradients and temperature drops across adjacent zones, and assuming q to remain constant, the velocity v may be calculated. Using this technique, vertical water flows of between 0.3 and 1.4×10^{-9} m/s (~ 0.3 and 1.4 ft/yr) have been calculated for the DT-1 temperature data. These calculations assumed a density of 1 gm/cm^3 for the effective water density in Equation (1). For absolute water flow velocities, the numbers given above should be divided by the fractional porosity of the strata (0.12 to 0.13, L. Chaturvedi, Chapter 10).

Unlike the measured gradients in DT-2 and the six shallow gradient holes, the gradient in DT-1 shows some curvature above the water table. This curvature prevents a direct comparison of the shallow gradient in DT-1 with the gradients in NMSU-8 and NMSU-9, although the DT-1 temperature at 30 m of 34.45°C (94.0°F) is higher than the temperatures in the two adjacent holes at the same depth, 34.25°C (93.6°F) and 33.79°C (92.8°F) for NMSU-8 and NMSU-9, respectively. Well DT-1 therefore appears to be close to the peak of the anomaly, and the curvature in the gradient above the water table may be due to a significant non-vertical component of heat flow close to the shallow source of the anomaly.

Conclusions And Future Studies

Borehole temperatures of the Las Alturas geothermal anomaly have partially defined the lateral extent of the anomaly, provided information

for the siting of deep tests, and confirmed the source of the anomaly to be a hydrothermal circulation system. Modelling of electrical resistivity data shows a 5 ohm-m low resistivity zone around the peak of the anomaly delineated by the shallow temperature gradient data (Smith 1977; Jiracek and Gerety 1978), but the borehole temperature data have provided better diagnostic information for delineating and interpreting the nature of the geothermal anomaly.

Before the end of 1979, it was planned to drill a deeper test well up to 750 m deep, into the geothermal system (L. Chaturvedi, personal communication). Further shallow gradient holes were planned over the center of the anomaly to provide information for the siting of this well. An extension of the heat flow analysis outlined above indicates a further decrease in the gradient below 300 m, with the temperature possibly increasing by as little as 1 to 4°C (2 to 7°F) at 750 m, giving a bottom hole temperature in the range of 64 to 67°C (147 to 153°F). This analysis assumes that the vertical water flow rates estimated for the zone from 300 m up to the water table are representative of the flow rates below 300 m. If this analysis is correct, the source of the hot water for the hydrothermal system could be groundwater circulation down to a depth of a little over 1 km, with a geothermal gradient typical for the area (i.e., 40°C/km, 2.2°F/100 ft). This extrapolation of the data uses many as yet unproven assumptions which, however, which only the drilling of the third deep well can test.

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Chapter 10

Analysis of Geological and Geophysical Logs of Two Geothermal Exploration Wells Drilled on NMSU Land, Las Cruces, New Mexico*

The Las Alturas geothermal area, which lies between Highway I-25 and Tortugas Mountain in the southeastern part of Las Cruces, has been under active investigation since at least 1975 (Gunaji et al. 1978; Jiracek and Gerety 1978; Swanberg 1975). In November 1978, the decision was made to drill two exploratory wells 1000 to 1500 feet deep, gathering information regarding the subsurface conditions such as stratigraphy, temperature gradient and groundwater. The locations of the two wells were determined on the basis of previous work completed, primarily electric resistivity and shallow temperature gradient surveys. The wells were drilled about 0.6 mile and 1 mile east, respectively, from the NMSU solar houses, south of the NMSU golf course along the dirt road going towards Tortugas Mountain. The locations of the two wells are shown in Figure 1.

The two wells, numbered NMSU-DG-1 and NMSU-DG-2 (New Mexico State University - Deep Geothermal Wells 1 and 2)** were drilled from 27 December 1978 to 3 January 1979 by Johnson Drilling Company of Las Cruces, using a rotary drilling rig. Well NMSU-DG-2 is located at a 52 feet higher ground elevation compared to well NMSU-DG-1 (4163 feet and 4111 feet above mean sea level, respectively). The bottom hole temperature in both wells was approximately 63°C.

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**In this Chapter 10, the geothermal wells DT-1 and DT-2 of Chapter 9 are referred to as NMSU-DG-2 and NMSU-DG-1, respectively.

Figure 1. Location of wells NMSU-DG-1 and NMSU-DG-2.

Geologic Setting

Figure 2 shows a generalized geologic map of the Las Cruces area, reproduced here from King and Hawley (1975). The area contains Paleozoic, Cretaceous and Tertiary sedimentary and volcanic rocks. Igneous intrusive rocks of Precambrian and Tertiary age make up the cores of the San Andres-Organ Mountain chain, Dona Ana Mountains, Goat Mountain and Picacho Mountain. Surface geologic material near the wells consists of unconsolidated basin fill alluvium of the Santa Fe Group. This material mainly consists of sand and gravel of coalescent alluvial-fan surfaces near the surface.

Since much of the unconsolidated material expected in these wells must have been transported from the Organ Mountains and Tortugas Mountain areas, a knowledge of rock types exposed in these outcrops is essential. Tortugas Mountain is the nearest rock outcrop and rocks exposed there consist primarily of Paleozoic sedimentary rocks, mainly limestone. A thick sequence of silicic volcanics consisting of basalt ash-flow tuffs (cueva tuff) and flow-banded rhyolite and ash-flow tuff (Soledad Rhyolite) is exposed in the Organ Mountains (Seager 1975). The Organ batholith consists of quartz monzonite, which is expected to yield fragments of quartz, feldspars, mica and clay minerals.

Geologic Log

Sampling Procedure. Samples were collected at 10-foot intervals from both wells. The material coming out of the well was passed through a screen to remove the drilling mud and then collected unwashed in canvas sample bags. Even though this method resulted in some samples being dried lumps, this approach yielded adequate data on the percentage of fines in

- REV
- 5 Valley-fill alluvium; late Quaternary; clay to gravel, less than 80 ft thick.
 - 6 Olivine basalt flows and volcanic cones; Quaternary, generally post date the Santa Fe Group.
 - 6a Basin-fill surface. Santa Fe Group, with discontinuous overlay (generally less than 25 ft thick) of younger alluvial, eolian and minor lacustrine deposits.
 - 6b Santa Fe Group basin fill; Miocene to middle Pliocene; clay to gravel; locally as much as 4,000 ft thick. Also discontinuous overlay (generally less than 100 ft thick) of younger valley slope deposits.
 - 7 Volcanic rocks, and associated elastic sedimentary rocks, undifferentiated; early and middle Tertiary.
 - 8 Sedimentary rocks, undifferentiated; Paleozoic, Cretaceous and early Tertiary.
 - 9 Intrusive rocks, undifferentiated, and associated metamorphics; Precambrian and Tertiary.
- Faults involving significant displacements of basin fill.

Figure 2. Generalized geological map of the Las Cruces area (King and Hawley, 1975).

each sample. The bags were numbered according to the depth of sample collection and stored for later study.

Laboratory Procedure. The samples were examined under a binocular microscope at 10x and 25x magnifications. Most samples were examined first unwashed and then again after washing them. Examination of unwashed samples gave an idea of the presence of fine material other than the drilling mud. Washing the sample made the identification of rock types much easier.

Interpretations. Figures 3 through 6 give summaries of the lithologic logs. These summaries were prepared following a detailed examination of 120 samples for NMSU-DG-1 and 100 samples for NMSU-DG-2. There is considerable similarity of lithologic horizons encountered by the two wells. The contacts encountered by NMSU-DG-2 are 20 to 50 feet higher than those found by NMSU-DG-1. This situation is to be expected, since the sediments (and flow?) are derived from the source area to the east and the dip is to the west. The eastern well (NMSU-DG-2) is also situated about 50 feet higher in elevation than NMSU-DG-1.

There are five major zones identified by lithologic logging. The top layer consists of sand and medium to coarse size gravel apparently derived from a host of rock types, namely, granitic intrusive rock, rhyolite flow, ash flow tuff, and others. The water table was encountered at about 265 feet below the ground surface in both wells and is clearly indicated by all geophysical well logs. Lithology below the water table is similar to that found above the water, except that some distinct layers of clay were encountered in sand and gravel. From about 420 feet down, the rock cuttings indicate a very uniform lithology, with the exception of an approximately 100-foot thick layer between 770 feet to 870 feet in

NMSU-DG-1 (NMSU DEEP GEOTHERMAL WELL NO. 1)

LOCATION: 1800' N, 2200' E, SEC. 27, TWP. 23S, R2E
 DOÑA ANA COUNTY, NEW MEXICO
 GROUND LEVEL: 4111 FEET ABOVE MEAN SEA LEVEL
 BIT SIZE: 5-1/8 INCHES
 DATE LOGGED: 1-3-1979

DEPTH (FEET)	LITHOLOGY	RESISTIVITY/SP	CALIPER	GAMMA-RAY	COMPENSATED NEUTRON	COMPENSATED DENSITY LOG
0	SAND AND GRAVEL, SOME CLAY, ROUNDED TO SUBROUNDED (QUARTZ, FELDSPARS, RYHOLITE, IGNEOUS ROCKS)	HIGH RESISTIVITY ($\approx 100 \text{ ohm-m}$) (DRY SAND AND GRAVEL)	MINOR FLUCTUA- TIONS	UNIFORM 100 API UNITS (LOW)	4-10%	4-10%
50						
100						
150						
200	COURSE GRAVEL AND SAND	LOW, 2-3 ohm-m	MINOR FLUCTUA- TIONS	FLUCTUATING	FLUCTUATING	FLUCTUATING
250	SAND AND CLAY	LOW, 2-3 ohm-m		FLUCTUATING		
300	LIMESTONE GRAVEL AND CLAY	6-9 ohm-m		UNIFORM 80 API	22-30%	22-30%
350	GRAVEL SAND, CLAY (RYHOLITE, LIMESTONE IGNEOUS ROCKS SUBROUNDED)	FLUCTUATING, 2-20 (ALTERNATING LAYERS OF CLAY, SAND, GRAVEL)		WILD FLUCTUATIONS 100-200 API	(WATER SAT.)	(WATER SAT.)
400						
450						
500	ANGULAR TO SUBANGULAR APPROX. 1/4" FRAGMENTS OF RYHOLITE, ANDESITE, RYHOLITIC ASH- FLOW TUFF, NO SAND OR CLAY.	VERY UNIFORM $\approx 15 \text{ ohm-m}$	MINOR FLUCTUA- TIONS	OFF SCALE CONDITION $\approx 200 \text{ API}$ (HIGHLY RADIOACTIVE FORMATION)	14-20%	14-20%
550						
600						
650						
700						
750						
800	SAND AND GRAVEL	LAYERS OF 3 ohm-m AND 10 ohm-m FLUCTUATIONS		WILD FLUCTUATIONS 100-200 API	FLUCTUATING	FLUCTUATING
850	COURSE SAND				14-30%	14-30%
900		VERY UNIFORM			12-15%	12-15%
950	ANGULAR TO SUBANGULAR, APPROX. 1/4" FRAGMENTS OF RYHOLITE, RYHOLITIC ASH-FLOW TUFF, ETC.	EXCEPT A 5 FT. LAYER AT 950-955' (FRACTURED RYHOLIT WITH NOT WATER IN FRACTURES P)	RUGGED WALL (MUCH FLUCTUA- TIONS)	OFF SCALE CONDITION (HIGHLY RADIOACTIVE FORMATION)	22%	22%
1000					12-15%	12-15%
1050						
1100					14-20%	14-20%
1150						
1200						

Figure 3. Summary of all logs for NMSU-DG-1.

NMSU-DG-1 (NMSU DEEP GEOTHERMAL WELL NO. 1)

INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS

DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, VARIETY OF IGNEOUS ROCKS, ETC. PROBABLY SANTA FE GROUP BASIN FILL. DRY. ABOVE THE WATER TABLE.
50		
100		
150		
200		
250		WATER TABLE AT 265 FT. BETWEEN 265 FT. AND 450 FT. THE SECTION CONSISTS OF LAYERS OF SAND, GRAVEL AND CLAY WITH LITHOLOGIC REPRESENTATION OF RHYOLITE, OTHER IGNEOUS ROCKS AND LIMESTONE (?). ASSOCIATED SAND IS INVARIABLY CALCAREOUS SATURATED SANTA FE GROUP BASIN FILL.
300		
350		
400		
450		FROM 450 FT. TO ABOUT 770 FT., ALL LOGS SHOW A VERY UNIFORM SECTION. CUTTINGS FROM DRILLING YIELD ANGULAR TO SUBANGULAR FRAGMENTS WITH AN AVERAGE OF 1/4" DIAMETER OR FINER. LITHOLOGY CONSISTS OF ALMOST 100% RHYOLITIC ROCK FRAGMENTS, WHICH SOMETIMES SHOW BANDED TUFF FEATURES AND SOME PIECES APPEAR GREYISH LIKE ANDESITIC ROCK. IS IT A FANGLOMERATE DEPOSIT OR FRACTURED RHYOLITIC FLOW?
500		
550		
600		
650		
700		
750		
800		LENSES OF SAND AND GRAVEL, COURSE SAND AND CLAY CONSISTING OF MORE HETEROGENEOUS LITHOLOGY THAN ABOVE. PROBABLY CONTAINS WATER.
850		
900		LITHOLOGY AND TEXTURE VERY SIMILAR TO THE 450-770 FT. ZONE. RESISTIVITY, GAMMA RAY, COMPENSATED NEUTRON AND COMPENSATED DENSILOG VERY SIMILAR TO THE ABOVE ZONE AS WELL. CALIPER SHOWS RUGGED WALL CONDITIONS. AT 950 FT. HEAVY MUD LOSS WAS ENCOUNTERED. RESISTIVITY SHOWS A LOW RESISTIVITY LAYER AND NEUTRON AND DENSILOG SHOW A HIGH POROSITY ZONE ABOUT 5 FT. POSSIBLY A FRACTURED ZONE WITH HOT WATER.
950		
1000		
1050		
1100		
1150		
1200		

Figure 4. Interpreted composite log of NMSU-DG-1.

NMSU-DG-2 (NMSU DEEP GEOTHERMAL WELL NO. 2)

LOCATION: 1000 + FNL, 500 + FEL, SEC. 27, TWP 23S, R2E
 DONA ANA COUNTY, NEW MEXICO
 GROUND LEVEL 4163 FEET ABOVE MEAN SEA LEVEL
 BIT SIZE 5-7/8 INCHES
 DATE LOGGED: 1-4-1979

DEPTH (FEET)	LITHOLOGY	RESISTIVITY/SP	CALIPER	GAMMA-RAY	COMPENSATED NEUTRON%	COMPENSATED DENSITY
0	SAND AND GRAVEL, SOME CLAY. ROUNDED TO SUBROUNDED (QUARTZ, RHYOLITE, IGNEOUS ROCKS)	HIGH RESISTIVITY (DRY SAND AND GRAVEL)	UNIFORM 5 FT.	UNIFORM 80-100 API UNITS	6-10%	4-10%
30						
100						
150						
200						
250				FLUCTUATIONS		
300	COARSE GRAVEL AND SAND	LOW RESISTIVITY, MINOR FLUCTUATIONS	7-12 INCHES	80-160 API UNITS	22-30%	22-30%
350	SAND WITH SOME GRAVEL.	(WATER SATURATED SAND AND GRAVEL WITH SOME CLAY LAYERS)	7-12 INCHES		(WATER SAT.)	(WATER SAT.)
400	SAND AND GRAVEL		7-12 INCHES			
450						
500	SUBANGULAR TO SUBROUNDED FRAGMENTS, MOSTLY RHYOLITE AND ANDESITIC ASH FLOW TUFF APPROX. 1/4 INCH PIECES	VERY UNIFORM RESISTIVITY PROFILE AT 10-20 OHM-FT. VERY LITTLE SEPARATION BETWEEN DEEP INDUCTION AND SHALLOW FOCUSED LOGS	MANY ZONES OF CAVING 8" TO 10" THICK EACH (MAXIMUM HOLE DIAMETER IS 7 INCHES)	HIGH GAMMA-RAY > 200 API UNITS	16-20%	16-20%
550						
600						
650						
700						
750				100-160 API		
800	GRAVEL AND SAND OF VARIOUS COMPO. WITH SOME ROUNDED GRAVEL OF ANDESITE	LOW RESISTIVITY, MINOR FLUCTUATIONS (POSSIBLE WATER SAT. WITH SAND GRAVEL WITH CLAY LAYERS)		> 200 API	12-26%	12-26%
850				100-200 API		
900	FINE PIECES OF RHYOLITE SOME QUARTZ & FELDSPARS. ETC.	VERY UNIFORM RESISTIVITY PROFILE AT 10-15 OHM-FT. VERY LITTLE SEPARATION		> 200 API UNITS	12-16%	12-16%
950						
1000						

Figure 5. Summary of all logs for NMSU-DG-2.

NMSU-DG-2 (NMSU DEEP GEOTHERMAL WELL NO. 2)
INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS

DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL. PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, A VARIETY OF IGNEOUS ROCKS, ETC. HIGH RESISTIVITY. UNIFORM CALIPER WITH MINOR FLUCTUATIONS. UNIFORM GAMMA RAY AND UNIFORM LOW POROSITY DENSITOG AND NEUTRON. PROBABLY SANTA FE GROUP BASIN FILL. DRY. ABOVE THE WATER TABLE.
50		
100		
150		
200		
250		WATER TABLE CLEARLY INDICATED BY ALL LOGS AT 265FT BELOW SURFACE. FROM 265FT. DOWN TO ABOUT 420FT. THERE APPEAR TO BE LAYERS OF SAND AND GRAVEL ALTERNATING WITH LAYERS OF CLAY. LOW RESISTIVITY. CAVED ZONES, FLUCTUATING GAMMA RAY, HIGH POROSITY VALUES AND LITHOLOGY ALL INDICATE THIS.
300		
350		
400		
450		BETWEEN 420 AND 450FT. BELOW SURFACE DOWN TO 720FT. THERE IS A ZONE OF SUBANGULAR TO SUBROUNDED FRAGMENTS OF RHYOLITE, RHYOLITIC ASH FLOW TUFF, ANDESITE AND ANDESITE ASH FLOW TUFF - APPROX. 1/4 INCH DIAMETER PIECES OR FINER. UNIFORM RESISTIVITY AND HIGH GAMMA RAY FOR THIS ZONE.
500		
550		
600		
650		
700		
750		FROM 720FT. TO 850FT. THERE ARE GRAVEL AND SAND OF MORE HETEROGENEOUS COMPOSITION WITH SOME FLATTENED, ROUNDED GRAVELS OF ANDESITE.
800		
850		
900		FROM 850FT TO THE BOTTOM OF THE WELL, THE ZONE IS CHARACTERIZED BY VERY UNIFORM PROFILES OF RESISTIVITY, GAMMA RAY, NEUTRON AND DENSITOG. LITHOLOGY SHOWS FINE CHIPS OF RHYOLITE AND MINOR AMOUNTS OF QUARTZ, FELDSPARS, ETC.
950		
1000		

Figure 6. Interpreted composite log of NMSU-DG-2.

NMSU-DG-1 and a 130-foot layer between 720 feet to 850 feet in NMSU-DG-2. These layers consist of clearly fluvial subrounded gravel, and some clay of a heterogenous composition. The layers above and below this apparent fluvial zone present a problem which has not yet been completely resolved. The zones between 420 feet to 720 feet and from 850 feet to the bottom consist of very uniform, fine or medium (approximately 1/8" to 1/4") angular to subangular (and occasionally subrounded) fragments of rhyolite or rhyolitic tuff. It is tempting to identify these zones as rhyolite flows (perhaps Soledad Rhyolite) except that there are indications to the contrary. Although a majority of fragments sampled from both wells for these zones are angular, there are enough subangular/subrounded fragments to indicate that these fragments are transported some distance. Also, although the drilling through these zones was difficult, it was not sufficiently difficult to consider these zones as continuous rhyolite flow beds. These zones could possibly represent highly fractured rhyolite flows separated by a 100- to 150-foot thick sedimentary bed or could possibly represent alluvial fan or bajada deposits developed on rhyolitic bedrock. All geophysical logs attest to the uniformity of these zones. The question of proper identification of these zones is left here unresolved with the suggestion that in any future drilling through these zones, core sampling should be done through at least parts of these zones and the cores carefully analyzed.

Geophysical Logs

Introduction. Two sets of logs were run in each well soon after drilling was completed. The logs were run by the commercial logging firm, Dresser Atlas. One set, called "Dual Induction Focused Log", contained

spontaneous potential and three resistivity logs, namely, shallow focused, medium induction and deep induction. The second set, called "Compensated Densilog/Compensated Neutron", contained caliper, gamma-ray, compensated neutron and compensated densilog. Figures 3 through 6 give the interpretations of each of these logs. Figures A-1 and A-2 in the Appendix show the original logs for NMSU-DG-1 and NMSU-DG-2, respectively. Borehole geophysical logs have been successfully used by petroleum, mining, and (to a lesser extent) groundwater industries for almost half a century or more. Log interpretation techniques have, therefore, been perfected for sedimentary strata analysis. Log interpretation of logs run in igneous rocks sequences generally rely on known properties of such materials and how these properties may affect various logging parameters. Not much interpretative literature is available on log interpretation for geothermal parameters identification (i.e., rock permeability, temperature vs. salinity, effects on resistivity, and spontaneous potential in igneous rock sequences).

The following is a summary of points of special interest concerning each log type.

Resistivity/Spontaneous Potential. Spontaneous potentials (SP) are usually produced by interactions between shale, interstitial water in sandstone, and drilling fluid. Since there are no classic shale, sandstone, or limestone sequences here, the SP curve is generally flat and does not contain much useful information.

Resistivity contrasts also are not as pronounced here as would be expected in a classic sedimentary sequence. However, induction and shallow focused resistivity profiles are used here to identify water-bearing gravel beds from an essentially dry and uniform rhyolite rock matrix.

Caliper. A caliper log has been used to delineate areas of caving and of rugged rock-like section. It has also been used to correctly interpret other logs, since in caved areas, other log responses are seriously affected by the borehole fluids rather than by formation properties.

Gamma Ray. A gamma-ray log is a passive log and counts natural radiation without providing any stimulation. In sedimentary sequences, a gamma-ray log is commonly known as a shale log, since potassium 40 found in shales show a high response. In the two holes presently under discussion, the gamma-ray logs showed high values (>200 A.P.I. units) against rhyolite zones. This situation is to be expected, since rhyolite has abundant potassium feldspar (orthoclase) and potassium mica (sericite/muscovite), which contain radioactive potassium 40.

Neutron/Densilog Porosity. These logs are a measure of hydrogen ion concentration in the formation rock. The highest porosity in both the wells is indicated, as would be expected, against water saturated gravel and sand just below the water table. However, fairly high porosity (e.g., 16 to 20 percent in the upper rhyolite layer, 12 to 16 percent in the lower rhyolite layer) is indicated against rhyolite layers. This situation could be due to water trapped within crystals in igneous rocks in minerals such as biotite and hornblende. There must be water in fractures as well. Therefore, the porosity indicated is most likely much higher than the actual porosity of these zones. Densilog is a variation of neutron logging and both provide almost identical values for each strata.

Interpretations

There is a good correspondence between responses recorded by each logging tool. Thus, the sand and gravel layers show relatively high resistivity (~ 100 ohm-m), uniform and relatively low gamma-ray response (80

to 100 A.P.I. units), and low neutron/densilog porosity all of which indicate dry conditions. Alternating layers of sand/gravel and clay show fluctuating resistivity, caving zones in caliper log, fluctuating gamma-ray response (high against clay due to presence of potassium 40), and fluctuating porosity log response.

The water table is clearly indicated by all logs. Resistivity curves record a sharp decrease after some fluctuations, perhaps due to the presence of capillary water above the actual water table. The highest porosity values are indicated by neutron and densilog against the water saturated zones.

Against rhyolite zones, resistivity values are higher and uniform throughout, gamma-ray response is highest (200 A.P.I. units), and porosity values are relatively high at 14 to 20 percent.

Conclusions

After careful site selection, two exploratory geothermal wells were drilled on New Mexico State University property in the southeastern part of Las Cruces. One of the wells was drilled to a depth of 1200 feet and the other to 1000 feet. Both wells encountered a groundwater table at a depth of 265 feet. An analysis of lithologic log and geophysical logs (i.e., resistivity, spontaneous potential, caliper, gamma ray, neutron porosity and densilog porosity) shows that both wells encountered essentially the same subsurface geology.

In this area, the top 450 feet appears to consist of gravel with some clay layers belonging to the Santa Fe Group of basin fill. Underlying this zone, rhyolite gravels were encountered between 450 and 750 feet and again between 850 feet and the bottom of the wells, with an intermediate layer of

gravel and sand of heterogeneous composition. It has not been determined as yet whether the rhyolite gravels represent a rhyolite flow, such as the extension of Soledad Rhyolite encountered in the Organ Mountains or a deposit of short distance transported material, such as an alluvial fan or bajada slope deposit. The bottom-hole temperature in both wells was approximately 63°C.

Acknowledgements

The help of Dr. N. N. Gunaji during drilling of the wells and arranging for sample collection is gratefully acknowledged.

Discussions with Professors William R. Seager and Robert Robinson of the Earth Sciences Department (NMSU) helped in clarifying some points regarding local geologic setting.

References

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- Jiracek, G. R., and M. T. Gerety, 1978, Comparison of surface and downhole resistivity mapping of geothermal reservoirs in New Mexico, Geoth. Res. Coun., Trans., vol. 2, pp. 335-336.
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APPENDIX

Copies of geophysical logs

Figure A-1. Geophysical logs of NMSU-DG-1.

Figure A-1. (continued).

Figure A-1. (continued).

Figure A-1. (continued).

Figure A-2. Geophysical logs of NMSU-DG-2.

Figure A-2. (continued).

Figure A-2. (continued).

Figure A-2. (continued).

Chapter 11

New Mexico State University Geothermal Production Well*

Location

The New Mexico State University geothermal production well (NMSU-PG-1) is located at 1,000 feet from North line, 500 feet from East line, Section 27, Township 23S, Range 2E, in Dona Ana County, New Mexico. The well is located at a ground level of 4,163 feet above mean sea level, approximately 1 mile east of Highway I-25, in Las Cruces, New Mexico. New Mexico State University owns the land and the mineral resources under the land at the site of the well. Figure 1 shows the location of the production well PG-1, as well as the two temperature gradient wells, DT-1 and DT-2.

Site Selection

The site for this well was selected on the basis of electrical resistivity surveys, shallow gradient wells and two deep exploration wells, DT-1 and DT-2. The geophysical work leading to the selection of the site for this well is described in Chapters 9 and 10. The analyses of geological and geophysical logs of the two deep exploration wells, which are reported in Chapter 10, formed the basis of the design of the production well (NMSU-PG-1).

*The principal author of Chapter 11 is Dr. Lokesh Chaturvedi, Associate Professor of Earth Sciences and Civil Engineering, New Mexico State University.

Figure 1. Location of exploratory wells DT-1 (1,000 feet), DT-2 (1,200 feet) and the production well PG-1 (850 feet).

Well Design

Figures 2 and 3 summarize the interpreted subsurface conditions encountered in wells DT-1 and DT-2, respectively. The production well (PG-1) was designed to tap the aquifer between 700 feet and 850 feet, as seen in Figure 2. A copy of the detailed technical specifications for the production well is given in Appendix A. The well was drilled according to these specifications without any cost-cutting modifications.

Logging

Lithologic samples (cuttings) were obtained for every 10 feet of drilling. Detailed lithologic analyses of these samples were performed under a binocular microscope at 10x and 25x magnifications. Samples of the source rocks from the Organ Mountains area were collected and the percentage of minerals and rocks found in each sample were determined. Results of the lithologic analysis are given in Appendix B. A suite of geophysical logs, consisting of electrical resistivity, spontaneous potential, gamma ray and neutron was run soon after the hole was drilled. These logs are included in Appendix C. The decision to install perforated pipe from the 700 feet to 850 feet depth was made on the basis of these logs. The temperature of the drilling fluid at the well head was continuously recorded during drilling of the production well. A plot of mud temperatures versus the depth of drilling is shown in Figure 4.

Well Development

The well was developed by bailing the water for 24 hours. A 70-gallon bailer brought out water at 55°C (131°F). From preliminary indications, it is anticipated that the well should be able to supply about 200 gallons per minute water at a temperature of approximately 60°C (140°F).

INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS		
DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, A VARIETY OF IGNEOUS ROCKS, ETC. HIGH RESISTIVITY, UNIFORM CALIPER WITH MINOR FLUCTUATIONS, UNIFORM GAMMA-RAY AND UNIFORM LOW POROSITY DENSIOLOG AND NEUTRON PROBABLY SANTA FE GROUP BASIN FILL. DRY ABOVE THE WATER TABLE.
50
100
150
200
250		WATER TABLE CLEARLY INDICATED BY ALL LOGS AT 265FT BELOW SURFACE. FROM 265FT. DOWN TO ABOUT 420FT, THERE APPEAR TO BE LAYERS OF SAND AND GRAVEL ALTERNATING WITH LAYERS OF CLAY. LOW RESISTIVITY, CAVED ZONES, FLUCTUATING GAMMA RAY, HIGH POROSITY VALUES AND LITHOLOGY ALL INDICATE THIS.
300
350
400
450
500		BETWEEN 420 AND 450FT. BELOW SURFACE DOWN TO 720FT., THERE IS A ZONE OF SUBANGULAR TO SUBROUNDED FRAGMENTS OF RHYOLITE, RHYOLITIC ASH FLOW TUFF, ANDESITE AND ANDESITE ASH FLOW TUFF - APPROX. 1/4 INCH DIAMETER PIECES OR FINER. UNIFORM RESISTIVITY AND HIGH GAMMA RAY FOR THIS ZONE.
550
600
650
700
750		FROM 720FT. TO 850FT., THERE ARE GRAVEL AND SAND OF MORE HETEROGENEOUS COMPOSITION WITH SOME FLATTENED, ROUNDED GRAVELS OF ANDESITE.
800
850		FROM 850FT TO THE BOTTOM OF THE WELL, THE ZONE IS CHARACTERIZED BY VERY UNIFORM PROFILES OF RESISTIVITY, GAMMA RAY, NEUTRON AND DENSIOLOG. LITHOLOGY SHOWS FINE CHIPS OF RHYOLITE AND MINOR AMOUNTS OF QUARTZ, FELDSPARS, ETC.
900
950
1000

Figure 2. Interpreted Subsurface Conditions in DT-1.

INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS		
DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, VARIETY OF IGNEOUS ROCKS, ETC. PROBABLY SANTA FE GROUP BASIN FILL. DRY. ABOVE THE WATER TABLE.
50		
100		
150		
200		
250		WATER TABLE AT 265 FT. BETWEEN 265 FT. AND 450 FT. THE SECTION CONSISTS OF LAYERS OF SAND, GRAVEL AND CLAY WITH LITHOLOGIC REPRESENTATION OF RHYOLITE, OTHER IGNEOUS ROCKS AND LIMESTONE (?). ASSOCIATED SAND IS INVARIABLY CALCAREOUS. SATURATED SANTA FE GROUP BASIN FILL.
300		
350		
400		
450		
500		FROM 450 FT. TO ABOUT 770 FT., ALL LOGS SHOW A VERY UNIFORM SECTION. CUTTINGS FROM DRILLING YIELD ANGULAR TO SUBANGULAR FRAGMENTS WITH AN AVERAGE OF 1/4" DIAMETER OR FINER. LITHOLOGY CONSISTS OF ALMOST 100% RHYOLITIC ROCK FRAGMENTS, WHICH SOMETIMES SHOW BANDED TUFF FEATURES AND SOME PIECES APPEAR GREYISH LIKE ANDESITIC ROCK. IS IT A FANGLOMERATE DEPOSIT OR FRACTURED RHYOLITIC FLOW?
550		
600		
650		
700		
750		LENSES OF SAND AND GRAVEL, COARSE SAND AND CLAY CONSISTING OF MORE HETEROGENEOUS LITHOLOGY THAN ABOVE. PROBABLY CONTAINS WATER.
800		
850		LITHOLOGY AND TEXTURE VERY SIMILAR TO THE 450-770 FT. ZONE. RESISTIVITY, GAMMA-RAY, COMPENSATED NEUTRON AND COMPENSATED DENSILOG VERY SIMILAR TO THE ABOVE ZONE AS WELL. CALIPER SHOWS RUGGED WALL CONDITIONS. AT 950 FT. HEAVY MUD LOSS WAS ENCOUNTERED. RESISTIVITY SHOWS A LOW RESISTIVITY LAYER AND NEUTRON AND DENSILOG SHOW A HIGH POROSITY ZONE ABOUT 5 FT. POSSIBLY A FRACTURED ZONE WITH HOT WATER.
900		
950		
1000		
1050		
1100		
1150		
1200		

Figure 3. Interpreted Subsurface Conditions in DT-2.

Figure 4. Mud temperature at well head for the NMSU Geothermal Production Well, PG-1.

Appendix A
Technical Specification for
Well NMSU-PG-1

NEW MEXICO STATE UNIVERSITY
Las Cruces, New Mexico

SECTION I

NOTICE TO BIDDERS

New Mexico State University, an Equal Employment Employer, requests bids for drilling a hot water production well about 2 miles east of the New Mexico State University campus in Las Cruces, New Mexico.

Bids will be opened at _____, 1979, in the office of the Director of Purchasing at the main campus of New Mexico State University in Las Cruces, New Mexico. Bids not received by opening time will be returned unopened.

The site may be inspected between the hours of 8:00 a.m. and 5:00 p.m. Monday through Friday by contacting Dr. Lokesh Chaturvedi, Professor of Civil Engineering (Telephone: (505) 646-3233), or Dr. Harry Beyer, Consultant to the New Mexico Energy Institute (Telephone: (505) 646-2493).

If the bid amount exceeds \$20,000 a Bid Bond payable to New Mexico State University in an amount of not less than 5% of the largest possible total bid submitted must accompany each bid as a guarantee that, if awarded the bid, the bidder will enter into a contract with the University. If successful, the vendor will be required to submit a 100% Performance Bond payable to New Mexico State University to guarantee that the vendor will promptly commence and complete all work as called for in these specifications. Reference is made to the Public Works Act 6-6-11 where the Owner is required to obtain a bond on the work in excess of \$500. If the bid amount is over \$20,000, the 100% Performance Bond will take the place of this Surety Bond. If the amount is under \$20,000, no 5% Bid Bond will be required, and the 100% Performance Bond will be substituted with a 50% Surety Bond. (A personal surety in the form of a check - cashiers or personal 0 may be substituted for the Bond, but must be in the amount of 100% of the bid instead of 50%).

6-6-11. Bonds of public contractors--Sureties.--Whenever any contract shall be entered into with the state or any county, municipality, district department board, or public corporation thereof, for the construction, alteration, improvement or repair of any public building, structure or highway, or for any public work the contract price for which exceeds five hundred dollars (\$500), the contractor shall, before beginning work thereunder, furnish a bond executed by the contractor and some surety company authorized to do business in the state, or any suitable sureties to be approved by the state board of finance in an amount equal to fifty percent (50%) of the contract price, conditioned for the performance and completion of such contract according to its terms, compliance with all requirements of law, and the payments as they become due of all just claims for labor performed, and materials and supplies furnished, upon or for the work under said contract, whether said labor be performed, and said materials and supplies be furnished under the original con-

tract or under any subcontract. The said bond shall be in form as approved by the attorney general, district attorney, or attorney for the obligee in said contract and as to sureties subject to approval of the authorities letting the contract. Personal sureties may be accepted if the authorities letting the contract so determine, but in such case the amount of the bond shall be the full contract price and the sureties shall justify under oath in amounts above liabilities and exemptions aggregating double the amount of the bond.

The New Mexico State University reserves the right to reject any or all bids and to waive any or all formalities.

Should any doubt or questions arise respecting the true meaning of these specifications, reference shall be made to the Owner's Representative, whose decision thereon shall be final: Dr. Lokesh Chaturvedi, Civil Engineering Department, New Mexico State University, Las Cruces, N.M. (Telephone: (505) 646-3233), or Dr. Harry Beyer, New Mexico Energy Institute, New Mexico State University, Las Cruces, N.M. (Telephone: (505) 646-2493).

Bidders are required to inform themselves fully of the conditions relating to the locations and labor required for the execution of this work.

Attention is called to the fact that the inclusion of a schedule of minimum wages to be paid employees engaged in work under this contract does not relieve the Contractor from compliance with any State Wage Law of any Municipality, and must pay not less than the rates legally prescribed or as set forth herein, whichever is higher. The wage rates shall only be applicable if the proposal is over Two Thousand Dollars (\$2,000).

In case of a difference in written words and figures in a proposal, the amount stated in written words shall govern. It is the Bidder's responsibility to deliver its bid proposals at the proper time to the proper place. The mere fact that a bid proposal was dispatched will not be considered. The Bidder must have the proposal actually delivered.

All bid proposals must be made upon the blank form of the Proposal attached hereto and should give the price by lot number for the work, both in written words and figures, and must be signed and acknowledged by the Bidder, in accordance with the directions in the Proposal. In order to insure consideration, the Proposal should be enclosed in a return envelope, marked, "Proposal, Do Not Open Until _____," and addressed to the Director of Purchasing, New Mexico State University, Las Cruces, New Mexico.

Within 30 days after the opening of the Proposals, the Owner will act upon them. The acceptance of the Proposal will be a notice in writing signed by a duly authorized representative of the Owner, and no

act of the Owner shall constitute the acceptance of a proposal.

The rights and obligations provided for in the Contract shall become effective and binding upon the parties only with its formal execution by both parties.

In the event that New Mexico State University employs attorneys or incurs other expenses it may deem necessary to protect or enforce its rights under this contract, the other party must agree to pay the attorney's fees and expenses so incurred by New Mexico State University.

The contractor must be willing to sign a contract for the specifications or option selected by the university by September 24, 1979. Preference will be given to contractors who can guarantee to complete the job within 60 days of signing the contract.

SECTION II

TECHNICAL SPECIFICATIONS

AND INFORMATION FOR BIDDERS

General description

These specifications are for drilling a hot water production well east of the NMSU campus, about 1 mile east of Interstate 25. An approximate description of the job is:

1. Drill a 17-inch hole to 850 feet.
2. Run a string of 100 feet of 10-inch screen and 750 feet of 10-inch casing.
3. Set a cement plug in the bottom of the hole.
4. Gravel pack 150 feet, and sand pack 30 feet of the 3-inch annular space.
5. Cement the remaining 3-inch annular space from 670 feet to the surface.

Location

The well is to be drilled on New Mexico State University land east of the campus. The site will be near well NMSU-DG-2 shown in Figure A-1, and is accessible by about one mile of dirt road. Bidders will be held as having examined the drilling site in order to acquaint themselves with the conditions of the roads and terrain. If road grading or clearing is necessary, the bidder shall notify the university in writing at the time of submission of the bid.

Figure A-1. Location of wells NMSU-DG-1 and NMSU-DG-2.

Local Conditions and Geology

Figures A-2 and A-3 give interpreted logging and lithologic data for well NMSU-DG-2. The data for well NMSU-DG-1 are nearly identical. The actual logs, cutting samples, and information for estimating penetration rate, can be seen by contacting Dr. Lokesh Chaturvedi, Department of Civil Engineering, New Mexico State University, phone number 646-3233.

Well NMSU-DG-2 reaches a maximum temperature of 63°C (145°F) at the bottom of the hole at 1000 feet. Well NMSU-DG-1 reaches a maximum temperature of 51°C (123°F) at a depth of 525 feet, and displays lower temperatures on down to TD at 1200 feet.

This information is given as a guide to the driller; however, geologic conditions at the site are not guaranteed by the university.

Equipment and Personnel To Be Furnished by the Contractor

The contractor shall provide the necessary rotary drilling rig, all tools, equipment, accessories, water, mud, power, bits, lighting, well casing, screen, cement, gravel, sand, and experienced personnel necessary to conduct without difficulty the drilling, casing, and cementing operation described in these specifications.

Equipment and Personnel To Be Furnished by the University

Samples of drill cuttings will be obtained at 10-foot intervals by university personnel, and will be put in containers supplied by the university.

Geophysical logging of the hole before the casing is run will be handled by the university.

NMSU-DG-2 (NMSU DEEP GEOTHERMAL WELL NO. 2)

INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS

DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, A VARIETY OF IGNEOUS ROCKS, ETC. HIGH RESISTIVITY. UNIFORM CALIPER WITH MINOR FLUCTUATIONS. UNIFORM GAMMA-RAY AND UNIFORM LOW POROSITY DENSIOLOG AND NEUTRON. PROBABLY SANTA FE GROUP BASIN FILL. DRY. ABOVE THE WATER TABLE.
60		
100		
150		
200		
250		WATER TABLE CLEARLY INDICATED BY ALL LOGS AT 265FT BELOW SURFACE. FROM 265FT. DOWN TO ABOUT 420FT, THERE APPEAR TO BE LAYERS OF SAND AND GRAVEL ALTERNATING WITH LAYERS OF CLAY. LOW RESISTIVITY, CAVED ZONES, FLUCTUATING GAMMA-RAY, HIGH POROSITY VALUES AND LITHOLOGY ALL INDICATE THIS.
300		
350		
400		
450		
500		BETWEEN 420 AND 450FT. BELOW SURFACE DOWN TO 720FT, THERE IS A ZONE OF SUBANGULAR TO SUBROUNDED FRAGMENTS OF RHYOLITE, RHYOLITIC ASH FLOW TUFF, ANDESITE AND ANDESITE ASH FLOW TUFF - APPROX. 1/4 INCH DIAMETER PIECES OR FINER. UNIFORM RESISTIVITY AND HIGH GAMMA-RAY FOR THIS ZONE.
550		
600		
650		
700		
750		FROM 720FT. TO 850FT, THERE ARE GRAVEL AND SAND OF MORE HETEROGENEOUS COMPOSITION WITH SOME FLATTENED, ROUNDED GRAVELS OF ANDESITE.
800		
850		
900		
950		
1000		FROM 850FT TO THE BOTTOM OF THE WELL, THE ZONE IS CHARACTERIZED BY VERY UNIFORM PROFILES OF RESISTIVITY, GAMMA-RAY, NEUTRON AND DENSIOLOG. LITHOLOGY SHOWS FINE CHIPS OF RHYOLITE AND MINOR AMOUNTS OF QUARTZ, FELDSPARS, ETC.

Figure A-2. Interpreted composite log of NMSU-DG-2.

NMSU-DG-2 (NMSU DEEP GEOTHERMAL WELL NO.2)

LOCATION: 1000' ± FNL, 500' ± FEL, SEC. 27, TWP. 23S, R2E
 DONA ANA COUNTY, NEW MEXICO
 GROUND LEVEL: 4163 FEET ABOVE MEAN SEA LEVEL
 BIT SIZE: 5-1/8 INCHES
 DATE LOGGED: 1-4-1979

DEPTH (FEET)	LITHOLOGY	RESISTIVITY/SP	CALIPER	GAMMA-RAY	COMPENSATED NEUTRON	COMPENSATED DENSLOG
0	SAND AND GRAVEL, SOME CLAY, ROUNDED TO SUBROUNDED (QUARTZ, RHYOLITE, IGNEOUS ROCKS)	HIGH RESISTIVITY (DRY SAND AND GRAVEL)	UNIFORM 5FT.	UNIFORM 80-100 API UNITS	6-10 %	6-10 %
50						
100						
150						
200						
250	COARSE GRAVEL AND SAND	LOW RESISTIVITY, MINOR FLUCTUATIONS	FLUCTUATIONS	80-160 API UNITS	27-30 %	27-30 %
300	SAND WITH SOME GRAVEL.	(WATER SATURATED SAND AND GRAVEL WITH SOME CLAY LAYERS)	KNIFE KNIFE KNIFE UNRAVED		(WATER SAT.)	(WATER SAT.)
350						
400	SAND AND GRAVEL					
450	SUBANGULAR TO SUBROUNDED FRAGMENTS, MOSTLY RHYOLITE AND ANDESITIC ASH FLOW TUFF - APPROX. 1/4 INCH PIECES	VERY UNIFORM RESISTIVITY PROFILE AT 10-20 ohm-m. VERY LITTLE SEPARATION BETWEEN DEEP INDUCTION AND SHALLOW FOCUSED LOGS	MANY ZONES OF CRAYING 2" TO 10" THICK EACH (MAXIMUM HOLE DIAMETER IS 7 INCHES)	HIGH GAMMA-RAY 700 API UNITS	16-20 %	16-20 %
500						
550						
600						
650						
700				100-160 API		
750	GRAVEL AND SAND OF VARIED COMPO. WITH SOME ROUNDED GRAVEL OF ANDESITE	LOW RESISTIVITY, MINOR FLUCTUATIONS (POSSIBLE WATER SAT. WITH SAND & GRAVEL WITH CLAY LAYERS)		700 API	12-26 %	12-26 %
800				100-200 API		
850						
900	FINE PIECES OF RHYOLITE, SOME QUARTZ & FELDSPARS, ETC.	VERY UNIFORM RESISTIVITY PROFILE AT 10-15 ohm-m VERY LITTLE SEPARATION		700 API UNITS	12-16 %	12-16 %
950						
1000						

Figure A-3. Summary of all logs for NMSU-DG-2.

The contractor will cooperate with the university in obtaining cuttings and performing logging.

Technical Specifications

1. Bore hole. The target production horizon shown in Figure A-2 is between about 720 and 850 feet. The hole shall be drilled to a depth of 850 feet. If the analysis of drill cuttings at this point indicates that the hole should be deeper to reach the bottom of this horizon, the university will pay the bid price per foot for any extra hole. It is not contemplated at this time to go more than 950 feet TD (total depth).

The diameter of the hole shall be such that after 10-inch minimum I.D. casing is installed, the annular space all around the casing shall be at least 3 inches wide. Thus, the minimum hole diameter shall be 16 3/4 inches.

The contractor should bear in mind that the university requires a hole sufficiently straight and plumb so that casing can be properly installed and gravel packed all around, that tools and bailers can be run freely to the bottom of the hole, and that a downhole pump with 300 gpm capability can be installed and operated at a depth of 450 feet.

2. Casing. The casing shall have a minimum inside diameter of 10 inches, and shall be Schedule 40 (e.g., for 10-inch I.D. pipe: 10.750 inches O.D., 40.48 #/foot, 0.365-inch wall thickness) new steel pipe, electric welded or seamless, with mill ends machined and beveled for welding. It is anticipated that about 750 feet of this blank casing will be installed.

The screen shall be the same type of pipe as the casing, with slots added. The length, width, and spacing of the slots shall be determined by

the university and the contractor based upon analysis of the drill cuttings. Centering guides shall be secured at the top, bottom, and at about 35-foot intervals along the screen assembly. At each of these locations, three guides will be attached, spaced at 120 degrees around the circumference of the screen. Each guide shall protrude at least 1 3/4 inch and no more than 2 1/4 inch beyond the surface of the screen. The portion of the hole to be screened will be determined by the university and the contractor based upon the geophysical logs. It is anticipated that about 100 feet of hole will be screened.

The casing and/or screen shall be welded together by the metallic arc process utilizing direct current, and is subject to approval by the university representative. All sections must be accurately aligned before welding. The casing ends shall be uniform, beveled, and welded utilizing at least three separate passes of the arc welder. Between each welding pass, the deposition of slag and scale will be removed. The contractor may utilize reinforcement straps if necessary. The contractor shall guarantee all welds to at least 75 percent of the ultimate strength of the casing tensile strength, and shall be responsible for all damage or costs resulting from failure of the weld or casing during construction of the well.

3. Bottom hole plug. A cement mix designed to harden in 24 hours shall be emplaced at the bottom of the hole to form a plug which is the full width of the hole and about 3-feet high. The casing string will be hanging in the hole so that its bottom end will be partly embedded in the cement plug. All down hole operations will cease for 24 hours to allow time for the cement to harden.

At a later date the well may be drilled deeper. The purpose of the cement plug is to prevent the gravel packing from falling down any new hole that is drilled.

4. Gravel and Sand Packing. The bottom of the hole to 50 feet above and top the screen (approximately 150 feet) and annular space between the casing and the well bore shall be packed with clean, screened pea gravel. The size of the gravel shall be determined by the university representative and the contractor based upon examination of the drill cuttings. The gravel shall contain little or no calcareous or organic material, such as limestone, shell fragments, wood fragments, or lignite, and shall be acceptable to the university representative. For the next 30 feet above the gravel, the annular space shall be packed with medium to coarse sand to prevent the intrusion of cement into the gravel packed production zone.

Prior to placement of gravel, all drilling fluid in the hole shall be thinned and conditioned to facilitate placement and settlement of the gravel. The contractor shall pay particular attention to mud weight and shall exercise caution to prevent caving of the hole.

The gravel and sand may be placed by pumping with water through a pipe run down the outside of the casing to the bottom of the hole and pulled back as the gravel or sand level rises in the annular space outside the screen assembly or casing. If gravel or sand is placed in the annular space at the surface of the ground, the casing shall be sealed to prevent mud from flowing up the inside of the casing; if this is not done, air could be introduced into the annular space, which might result in caving.

The contractor shall furnish and operate sounding equipment to check the gravel and sand level during placement.

5. Cementing. After the sand packing has been emplaced, about two barrels of cement will be placed on top of the sand packing (at a depth of about 670 feet) using a pipe run down the annular space outside the casing. This cement will be allowed to harden for 24 hours before additional cementing is undertaken. Then the rest of the annular space shall be filled to the surface with neat cement using a grout pipe or another method acceptable to the university representative.

6. Development. The well will be developed until it is cleaned of sand. It will be bailed for eight hours, or until a good water sample can be obtained.

Inspection

All casing and screen will be inspected by the university representative before it is placed in the hole.

Final Site Condition

The contractor will leave the top of the casing 4 feet above the ground level with a plate welded to the top.

The well site will be left clean and all tools and trash removed from the well site when the contractor removes the rig.

Driller's Logs

The driller shall keep a log indicating time, depth (if relevant), significant activities performed, observations, etc. A copy of this log will be supplied to the university.

Possible Cost-Cutting Modifications to the Technical Specifications

As a result of financial considerations, the university may have to modify or eliminate some items from the technical specifications given above. The modifications might reduce the possibility of drilling the well deeper at a later date, or might reduce productivity.

Option A

1. Bore hole. (Same as above).
2. Casing. (Same as above).
3. Bottom hole plug. Instead of emplacing a cement plug at the bottom of the hole, a cement plug will be allowed to harden in the bottom 2 feet of the bottom joint of screen on casing before it is lowered into the hole. (This will eliminate rig standby time waiting for the cement to harden).
4. Gravel and sand packing. (Same as above).
5. Cementing. The same procedure as above with the exception that cement will extend for only 200 feet above the sand packing. The rest of the annular space, from about 470 feet to the surface, will be filled with drill cuttings and heavy mud.
6. Development. (Same as above).

Option B

1. Bore hole. (Same as above).
2. Casing. (Same as above).
3. Bottom hole plug. (Same as in Option A).
4. Gravel packing. Gravel packing will be performed, as described above, to 50 feet above the top of the screen. However, no sand packing will be done.

5. No cementing will be done. Instead, the annular space from the top of the gravel (at about 700 feet) to the surface will be filled with drill cuttings and heavy mud.

6. Development. (Same as above).

Option C

For this program no gravel packing of the production zone will be attempted, so a smaller diameter bore hole can be drilled.

1. Bore hole. (The same target depth, and the same requirements for the hole to be straight and plumb, as described above).

The diameter of the hole shall be such that 10-inch I.D. casing (10.75-inch O.D.) can be inserted to TD, and a grouting pipe can be inserted in the annular space to a depth of 250 feet. It may be advantageous to run the grouting pipe into the hole before the casing.

2. Casing. (Same as above).

3. Bottom hole plug. (Same as Option A).

4. Bonnet. In order to cement the annular space from about 250 feet to the surface, a bonnet will be attached to the casing to prevent cement penetration below this depth. About 20 to 40 feet of sand packing material will be placed in the annular space on top of the bonnet, and then about two barrels of cement will be emplaced on the sand using the grouting pipe to form a cement plug. This plug will be allowed to harden for 24 hours.

5. Cementing. The annular space from 250 feet to the surface will be cemented using the grouting pipe.

6. Development. The well will be developed for eight hours or more until a good water sample can be obtained. This may require the use of a sand pump or suction-type bailer.

SECTION III

BID FORM

Place: _____

Date: _____

Project No: _____

Proposal of _____
(Hereinafter called Bidder) a corporation, partnership, or an individual.

TO: The Purchasing Agent
New Mexico State University
Las Cruces, New Mexico 88003

Gentlemen:

The Bidder, in compliance with your invitation for bids for drilling a warm water production well on New Mexico State University land east of the campus in Las Cruces, New Mexico, having examined the specifications and the site of the proposed work, and being familiar with all of the conditions surrounding the construction of the proposed project including the availability of materials, equipment and labor, hereby proposes to furnish all materials, equipment, labor, and supplies and to complete the project at the prices stated below. These prices are to cover all expenses incurred in performing the work, including taxes, as required in the specifications.

UNIT PRICES: For changing quantities of work items from those indicated by the contract specifications, upon written instructions from the university representative, the following unit prices shall prevail. These unit prices shall include all materials, labor, and equipment to cover the finished work of the several kinds called for.

Full program described in complete technical specifications

<u>BID LOT</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>UNIT PRICE</u>	<u>TOTAL PRICE</u>
#1	1	Mobilization, demobilization, clean-up	\$ _____	\$ _____
#2	850 ft.	Drill well bore	\$ _____	\$ _____
#3	4 hours	Standby time during logging, etc.	\$ _____	\$ _____
#4	100 ft.	Set screen	\$ _____	\$ _____
#5	750 ft.	Set casing	\$ _____	\$ _____
#6	1	Set bottom hole cement plug	\$ _____	\$ _____
#7	180 ft.	Gravel and sand pack annular space	\$ _____	\$ _____
#8	670 ft.	Cement annular space	\$ _____	\$ _____
#9	8 hours	Develop and clean out well	\$ _____	\$ _____

Bidder agrees to perform all work described in these specifications for the sum stated:
\$(_____)

OPTION A

<u>BID LOT</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>UNIT PRICE</u>	<u>TOTAL PRICE</u>
#1	1	Mobilization, demobilization, cleanup	\$ _____	\$ _____
#2	850 ft.	Drill well bore	\$ _____	\$ _____
#3	4 hours	Standby time during logging, etc.	\$ _____	\$ _____
#4	100 ft.	Set screen with cement plug already in bottom joint	\$ _____	\$ _____
#5	750 ft.	Set casing	\$ _____	\$ _____
#6	180 ft.	Gravel and sand pack annular space	\$ _____	\$ _____
#7	200 ft.	Cement annular space	\$ _____	\$ _____
#8	8 hours	Develop and clean out well	\$ _____	\$ _____

Bidder agrees to perform all work described in the Option A specifications for the sum stated:

\$ (_____)

OPTION B

<u>BID LOT</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>UNIT PRICE</u>	<u>TOTAL PRICE</u>
#1	1	Mobilization, demobilization, cleanup	\$ _____	\$ _____
#2	850 ft.	Drill well bore	\$ _____	\$ _____
#3	4 hours	Standby time during logging, etc.	\$ _____	\$ _____
#4	100 ft.	Set screen with cement plug already in bottom joint	\$ _____	\$ _____
#5	750 ft.	Set casing	\$ _____	\$ _____
#6	150 ft.	Gravel pack annular space	\$ _____	\$ _____
#7	8 hours	Develop and clean out well	\$ _____	\$ _____

Bidder agrees to perform all work described in the Option B specifications for the sum stated:

\$ (_____)

OPTION C

<u>BID LOT</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>UNIT PRICE</u>	<u>TOTAL PRICE</u>
#1	1	Mobilization, demobilization, cleanup	\$ _____	\$ _____
#2	850 ft.	Drill well bore	\$ _____	\$ _____
#3	4 hours	Standby time during logging, etc.	\$ _____	\$ _____
#4	100 ft.	Set screen with cement plug already in bottom joint	\$ _____	\$ _____
#5	750 ft.	Set casing	\$ _____	\$ _____
#6	1	Bonnet, installed in annulus with sand packing and cement plug at 250 ft.	\$ _____	\$ _____
#7	250 ft.	Cement annular space	\$ _____	\$ _____
#8	8 hours	Develop and clean out well	\$ _____	\$ _____

Bidder agrees to perform all work described in Option C specifications for the
sum stated:

\$ (_____)

ADDRESS OF FIRM:

RESPECTFULLY SUBMITTED:

BY: _____

DATE: _____

TITLE: _____

NEW MEXICO CONTRACTOR'S LICENSE NUMBER: _____

Appendix B

Lithologic Analysis of Cuttings

From Well NMSU-PG-1

DEPTH	MINERALOGY (%)												RICK TEXTURE	AVG. SIZE	REMARKS
	Qtz. Mns.	Qtz.	Tuff.	Rhy.	Ande.	Mica	Feld.	La.	Caliche	Ss.	Chert	Dark Ig. Rock			
10-20		30	20	10	5	-	-	5	30	-	-	-	rounded and subrounded	3 mm	free quartz and caliche cemented fines
20-30		20	40	20	-	-	5	5	10	-	-	-	rounded	4 mm	rounded edges with sharp faces (rounded prim.)
30-40	5	50	25	10	-	-	5	5	-	-	-	-	subangular to angular	2 mm	considerable clay
40-50	2	20	5	5	-	-	3	-	60	-	-	5	subrounded	.05 mm	questionable sample
50-60	20	20	10	10	-	5	5	15	10	-	-	5	subrounded subangular	5 mm	numerous smooth faces on chips (occasionally rounded)
60-70	15	20	15	15	5	-	5	15	5	-	-	5	subrounded subangular	5 mm	large rounded gravels, probably cave-in material
70-80	5	30	20	15	5	-	-	5	10	-	5	5	rounded to subrounded	4 mm	some chalcedony noted; smooth faces noted on chips
80-90	5	50	15	10	5	-	-	5	5	-	-	5	rounded to subrounded	4 mm	smooth faces on chips
90-100	10	50	10	10	3	-	2	-	5	-	-	10	rounded to subrounded	5 mm	smooth faces on chips; about half of quartz is .005 mm and caliche cements
100-110	5	40	15	10	5	-	5	-	5	-	10	5	subrounded to subangular	4 mm	still considerable caliche cemented quartz (.005 mm); angular fragments common
110-120	10	35	10	15	10	-	Trace	10	5	-	-	5	subrounded to subangular	3 mm	distinct Soledad Rhyolite present; numerous rounded fragments
120-130	5	25	20	25	15	-	Trace	5	2	-	-	3	subangular to angular some round faces on chips	3 mm	occasionally large (6 mm) pieces, probably cave-in material
130-140	Trace	20	30	35	5	-	-	5	-	-	-	5	subangular to angular some round faces on chips	3 mm	sandstone noted (Abo formation); some large rounded (6-7 mm) gravel
140-150	5	15	30	40	5	-	-	5	-	-	-	-	angular	4 mm	Cueva Rhyolite noted; few subangular & some rounded
150-160	Trace	40	30	10	10	Trace	5	-	-	-	-	5	subrounded to subangular	3 mm	Considerable caliche cemented quartz; (cave-in?) Numerous rounded dendrites on rhyolite
160-170	10	30	40	5	5	-	-	-	5	-	-	-	subangular to angular	3 mm	caliche cemented quartz sandstone; few rounded
170-180	3	40	35	15	5	Trace	Trace	-	1	1	-	-	subrounded to angular	4 mm	carbonate cement noted
180-190	5	30	25	20	10	-	-	-	5	-	-	5	subrounded	3 mm	Chips common with one rounded edge. Considerable well-rounded (2-3 mm) coarse sand.
190-200	1	20	10	40	2	2	-	-	5	15	2	3	subrounded to subangular	3 mm	sandstone with carbonate cement composed of >60% dark minerals, remainder qtz. (15% of sample)
200-210	-	30	10	50	2	-	Trace	-	2	5	-	1	subrounded to subangular	3 mm	very angular chips of rhyolite tuff noted
210-220	2	20	10	40	10	-	3	-	3	10	-	2	subrounded	3 mm	chips with one smooth face becoming more common; fewer well rounded grains noted
220-230	10	30	10	20	10	-	5	5	2	5	-	3	subrounded to subangular	2 mm	average grain size decreased
230-240	5	15	10	45	5	-	-	-	3	15	-	2	subangular	2 mm	large 4-5 mm well rounded gravel still present (uphole caving?)
240-250	5	25	5	50	5	-	1	-	3	5	-	1	subangular	2 mm	
250-260	5	20	15	40	10	-	-	2	3	5	-	-	subrounded to subangular	<2 mm	numerous very angular small chips present
260-270	3	22	10	40	5	-	-	-	3	10	2	5	subangular	2 mm	most grains are angular on at least one face
270-280	-	30	5	45	5	-	5	-	2	3	-	5	subrounded to subangular	3 mm	Very fine sand (<1 mm) typically well rounded. Numerous large, well rounded grains (4-5 mm) present.
280-290	5	3	10	40	40	-	-	-	-	2	-	-	subangular to angular	2 mm	30-40% clay. Volcanics are distinctly locally derived andesites (Orejon) and rhyolites (Cueva and Soledad) <5% of clastics are not locally derived. Previously <50% volcanics were locally derived.
290-300	-	10	10	45	30	-	-	-	2	3	-	-	subangular to angular	1.5 mm	Few rounded grains. ~60% clay. Chips are locally derived volcanics.
300-310	5	5	5	55	20	-	5	-	-	5	-	-			<40% clay. Weathered Soledad Rhyolite is sometimes difficult to distinguish from very fine grained sandstone.
310-320	-	20	15	50	5	-	-	3	5	2	-	-	subangular to angular	1 mm	60% clay. <50% of chips >1 mm
320-330	-	10	5	50	25	-	-	-	3	2	-	5	subangular to angular	1 mm	30% clay. Some chips have one or two rounded faces the remainder angular. None were entirely rounded.
330-340	-	3	5	25	2	-	-	-	60	5	-	-	angular	1 mm	60% clay. Several angular 3-6 mm diam. chips (rhyolite) noted. Chips examined are primarily recrystallized carbonates and carbonate-cemented siltstone.

Figure B-1. Lithologic analysis of cuttings from Well NMSU-PG-1.

DEPTH	MINERALOGY (2)												ROCK TEXTURE	AVG. SIZE	REMARKS
	Qtz. Monz.	Qtz.	Tuff	Rhy.	Ande.	Mica	Feld.	Ls.	Cal-sche	SS	Chert	Dark Ig. Rock			
340-350	-	5	5	10	-	-	-	-	75	5	-	-	subangular to angular	1.5 mm	70% clay. One large angular chip (8 mm diam) noted. Remainder of chips <2 mm. Chips are (recrystallized) carbonates.
350-360	-	10	10	60	5	-	-	-	10	-	-	5	subangular to angular	1.5 mm	40% clay. Several rounded quartz grains noted.
360-370	10	5	10	70	3	-	-	2	-	-	-	-	subrounded to subangular	2 mm	30% of initial sample clay. A few rounded grains noted.
370-380	5	5	10	70	5	-	-	-	-	5	-	-	subangular to angular	2 mm	Predominately Soledad Rhyolite. 20% clay.
380-390	2	5	10	75	5	-	-	-	-	-	-	5	angular	2 mm	10% clay. Soledad Rhyolite predominates.
390-400	-	5	5	80	5	-	-	-	-	-	-	5	angular	2 mm	~5% clay. The only rounded grains are 1.0 mm quartz.
400-410	-	5	10	65	15	-	-	-	-	-	-	5	subangular to angular	2 mm	15% clay. Considerable variation in appearance of rhyolite.
410-420	Trace	-	15	80	5	-	-	-	-	-	-	-	angular	3 mm	~2% clay. Soledad Rhyolite predominates. Some Cueva Rhyolite noted.
420-430	5	-	5	85	5	-	-	-	-	-	-	-	angular	3 mm	<1% clay. Cueva Rhyolite comprises less than 5% of total "rhyolite." "Flow banded rhyolite" is Soledad.
430-440	2	-	5	90	3	-	-	-	-	-	-	-	angular to very angular	4 mm	<1% clay. Soledad Rhyolite predominates.
440-450	5	-	5	90	-	-	-	-	-	-	-	-	angular	3 mm	~5% clay. Numerous angular rhyolite fragments 5 to 7 mm diam. Andesite is conspicuously absent.
450-460	-	-	5	90	5	-	-	-	-	-	-	-	angular to subangular	3 mm	<1% clay. Greater percentage of "red" rhyolites noted; ~10%.
460-470	-	-	3	95	2	-	-	-	-	-	-	-	angular	3 mm	<1% clay. Still considerable variation in color, flow banding, etc. in rhyolite.
470-480	-	-	8	90	2	-	-	-	-	-	-	-	subangular to angular	3 mm	<1% clay. Cueva Rhyolite comprises about 15% of sample; remainder of rhyolite is Soledad, which is still variable in features. Many chips have one weathered face.
480-490	2	-	5	90	1	-	-	-	-	-	-	2	subangular to angular	3 mm	<1% clay. Rhyolite variable.
490-500	-	-	2	95	3	-	-	-	-	-	-	-	angular	3 mm	<1% clay. ~10% of sample is Soledad Rhyolite chips 8-10 mm diam. Rhyolites variable.
500-510	-	-	3	96	1	-	-	-	-	-	-	-	angular to subangular	3 mm	<1% clay.
510-520	1	-	3	95	1	-	-	-	-	-	-	-	-	2 mm	<1% clay. Rhyolites are consistent in variation.
520-530	3	-	7	85	5	-	-	-	-	-	-	-	angular	3 mm	~5% clay. Rhyolites variable.
530-540	-	-	1	97	2	-	-	-	-	-	-	-	angular	3 mm	Chips are exceptionally clean. ~30% of rhyolite is "reddish" in color. Previous samples averaged ~10%. Most of remaining rhyolite is light purple basal Soledad. ~25% of chips have at least one weathered face.
540-550	-	-	2	93	5	-	-	-	-	-	-	-	subangular to angular	3 mm	same as above; about 10% of samples are rounded.
550-560	-	-	1	98	1	-	-	-	-	-	-	-	angular	-	Soledad rhyolite comprises ~95% of sample. Rounded grains are present (~5%).
560-570	-	-	3	96	1	-	-	-	-	-	-	-	angular	3 mm	Rhyolites are more variable in features than 530-560 samples. No carbonates.
570-580	-	-	1	98	1	-	-	-	-	-	-	-	angular to very angular	3 mm	Rhyolite chips are clean but variable in appearance. A few rounded grains noted.
580-590	-	-	5	94	1	-	-	-	-	-	-	-	angular	3 mm	15% of rhyolite is "reddish" in color (upper Soledad). ~60% of sample is light purple basal Soledad Rhyolite. ~5% is Cueva Rhyolite. ~30% of chips have at least one weathered face.
590-600	2	-	5	85	8	-	-	-	-	-	-	-	angular	3 mm	same as above
600-610	-	-	5	90	5	-	-	-	-	-	-	-	angular	4 mm	same as above
610-620	-	-	10	80	10	-	-	-	-	-	-	-	angular	4 mm	"Red" rhyolite comprises about 5% of sample. Most of remainder is Soledad Rhyolite.
620-630	-	-	5	93	2	-	-	-	-	-	-	-	angular to subangular	4 mm	same as 580-610 depth
630-640	1	-	5	90	2	-	-	2	-	-	-	-	angular to subangular	3 mm	same as 580-610 depth
640-650	-	-	5	96	1	-	-	-	-	-	-	-	angular	3 mm	same as 580-610 depth
650-660	-	-	2	96	1	-	-	1	-	-	-	-	angular to subangular	3 mm	"Red" rhyolite comprises about 10% of sample. Cueva Rhyolite <1%, remainder of rhyolite is Soledad from various members.
660-670	-	-	5	94	1	-	-	-	-	-	-	-	angular to subangular	2 mm	Same as above. ~30% of chips have one or more weathered faces.
670-680	1	-	2	95	2	-	-	-	-	-	-	-	angular to subangular	2 mm	Chips are very angular and of uniform size; many have at least one weathered face. "Red" rhyolite ~10% of sample; remainder is variable in appearance.

Figure B-1. (continued).

DT. FTH.	MINERALOGY (%)											Rock Texture	Avg. Size	REMARKS
	Qtz.	Qtz.	Tuff	Rhy.	Ande.	Mica	Feld.	Ls.	Cal- iche	SS	Chert			
680-690	-	-	5	93	2	-	-	-	-	-	-	angular	3 mm	Chips are very angular and of uniform size; many have at least one weathered face. "red" rhyolite ~5% of sample; remainder is variable in appearance.
690-700	-	-	3	96	1	-	-	-	-	-	-	angular		~5% of rhyolite is "red". Light purple basal Soledad Rhyolite ~70% of sample. ~5% is Cueva Rhyolite; remainder is undifferentiated Soledad.
700-710	-	-	5	90	5	-	-	-	-	-	-	angular	4 mm	Same as above. Chips 690-710 are mostly angular but 10-20% have one weathered face.
710-720	-	2	8	85	5	-	-	-	-	-	-	angular to subangular	3 mm	same as 690-710
720-730	-	2	2	93	1	-	-	-	-	-	-	angular	2 mm	same as 690-710
730-740	-	-	5	94	1	-	-	-	-	-	-	angular to subangular	4 mm	Numerous rounded, unbroken 2-3 mm grains of Soledad Rhyolite. Otherwise, same as 690-710.
740-750	-	1	2	96	1	-	-	-	-	-	-	subangular to angular	3 mm	~10% of rhyolite is "red" (probably upper Soledad Rhyolite). ~5% Cueva Rhyolite; remainder of rhyolite represents lower Soledad Rhyolite. Chips are primarily very angular with occasional weathered face; some rounded grains.
750-760	5	3	10	80	2	-	-	-	-	-	-	subangular to angular	3 mm	~2-3% clay. Numerous rounded grains. Otherwise, same as 740-750.
760-770	10	5	2	78	5	-	-	-	-	-	-	subrounded to subangular	4 mm	~15% clay. ~20% of sample is 5-7 mm pebbles, many of which are rounded. ~30% of sample (2-3 mm) is composed of rounded grains. Rhyolite percentages same as 740-750.
770-780	2	1	5	90	2	-	-	-	-	-	-	subangular	4 mm	~3% clay. Otherwise, same as 760-770.
780-790	-	1	2	96	1	-	-	-	-	-	-	subangular to angular	3 mm	~15% clay. Few rounded grains; most of sample is chips; about 30% of chips have one or more rounded, weathered sides. Rhyolite composition unchanged.
790-800	-	2	2	93	2	-	1	-	-	-	-	angular		~5% clay. Otherwise, same as 780-790.
800-810	-	1	3	95	1	-	-	-	-	-	-	angular		~2% clay. Sample is mostly rhyolite chips. Few rounded grains noted. Little variation in rhyolite composition with depth.
810-820	-	3	5	90	2	-	-	-	-	-	-	subangular to angular	3 mm	<1% clay. ~15% of sample is rounded grains. Otherwise, same as above.
820-830	-	1	2	96	1	-	-	-	-	-	-	subangular to angular	3 mm	~2% clay. ~15% of sample is rounded grains. Little variation in rhyolites.
830-840	-	1	5	90	3	-	1	-	-	-	-	angular	3 mm	same as 820-830, with exception that <5% of grains are rounded.
840-850	1	2	4	92	1	-	-	-	-	-	-	angular	3 mm	~20% "red" rhyolite. ~5% Cueva Rhyolite. ~20% basal Soledad Rhyolite; remainder of Soledad undifferentiated. Most of sample is chips; <5% of grains are rounded.
850-860	-	1	2	92	5	-	-	-	-	-	-	angular	3 mm	Same as 840-850. Chips are noticeably more uniform in size (2.5-3 mm).
860-870	-	1	4	94	1	-	-	-	-	-	-	angular to subangular	3 mm	Same as 840-850. ~30% chips have at least one weathered face.
870-880	-	1	4	95	-	-	-	-	-	-	-	angular to subangular	3 mm	same as 860-870 with exception that ~10% of grains are rounded.
880-890	1	1	3	94	1	-	-	-	-	-	-	subangular to angular	3 mm	same as 870-880
890-900	-	1	2	97	-	-	-	-	-	-	-	angular	2 mm	Rhyolite type percentages unchanged. 10-15% of 1-mm grains are rounded. A few larger grains are rounded; 20% of chips have at least one weathered face.
900-910	1	1	2	93	3	-	-	-	-	-	-	subangular to angular	3 mm	same as 890-900
910-920	-	1	7	91	1	-	-	-	-	-	-	angular	2 mm	same as 890-910
920-930	-	-	3	96	1	-	-	-	-	-	-	angular	4 mm	same as 890-920 except for noticeable lack of Cueva Rhyolite
930-940	-	-	4	95	1	-	-	-	-	-	-	subangular to angular	3 mm	same as 890-910 except Cueva Rhyolite present
940-950	-	1	8	90	1	-	-	-	-	-	-	subangular to angular	3 mm	same as 890-910
950-960	-	1	3	94	2	-	-	-	-	-	-	subangular to angular	4 mm	Rhyolite type percentages unchanged. Chips are no longer of uniform size. 10-15% of sample is 5-7 mm very angular rhyolite chips. 8-10% of grains are rounded.
960-970	-	1	2	95	2	-	-	-	-	-	-	subangular to angular	3 mm	Same as 950-960. 30-40% of chips have at least one weathered face.
970-980	1	1	3	93	2	-	-	-	-	-	-	subangular to angular	4 mm	same as 950-970
980-990	-	1	1	97	1	-	-	-	-	-	-	angular	3 mm	same as 950-980
990-1000	-	1	2	95	2	-	-	-	-	-	-	angular	3 mm	Chips are uniform in size (1.5-2 mm). Rhyolite type percentages remain unchanged. 5-7% of grains are rounded. 15-25% of chips have at least one weathered face.

*Since DT-1 is only about 15 feet away from PG-1 and the well cuttings were identical from the two wells, the analysis of cuttings from DT-1 were used for the interval 860 to 1000 feet.

Figure B-1. (continued).

Appendix C

Geophysical and Temperature Logs and Vertical Deviation Survey for Well

NMSU-PG-1

OF THE

3

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-1. (continued).

Figure C-2. Temperature log for well NMSU-PG-1.

Figure C-2. (continued).

CENTURY GEOPHYSICAL CORPORATION								
*** VERTICAL DEVIATION SURVEY ***								
COMPU-LUG Y3L1 DEVIATION								
HOLE ID: EAST PRODUCTION WELL								
TD = TOTAL DEPTH								
T = TOP OF ZONE								
B = BOTTOM OF ZONE								
DEPTH	TRUE DEPTH	NORTH DEY.	EAST DEY.	DISTANCE	AZIMUTH	SR	SAB	
.0	.00	.00	.00	0	.0	.0	.0	
50.0	49.99	-.07	-.08	.1	229.6	.1	229.6	
100.0	99.99	.08	.01	.0	18.2	.2	32.3	
150.0	149.99	.24	-.29	.3	318.1	.3	297.1	
200.0	199.99	-.01	-.45	.4	268.6	.3	212.3	
250.0	249.99	.07	-.63	.6	272.1	.2	296.2	
300.0	299.99	-.17	-.80	.8	257.7	.3	213.8	
350.0	349.98	-.35	-1.12	1.1	252.2	.4	239.8	
400.0	399.98	-.13	-1.34	1.3	264.1	.3	313.7	
450.0	449.98	.11	-1.67	1.6	273.9	.4	382.9	
500.0	499.98	.21	-2.23	2.2	275.4	.5	279.9	
550.0	549.97	-.12	-2.72	2.7	267.2	.6	235.0	
600.0	599.97	-.36	-2.89	2.9	262.9	.3	215.7	
650.0	649.97	-.16	-3.20	3.2	266.9	.4	381.3	
700.0	699.96	.08	-4.05	4.0	271.1	1.0	286.3	
750.0	749.95	.08	-5.11	5.1	270.9	1.2	270.1	
800.0	799.94	.08	-6.18	6.1	270.7	1.2	269.8	
850.0	849.93	.14	-7.02	7.0	271.1	.9	274.2	
TD 861.0	860.93	.20	-7.22	7.2	271.6	1.1	286.8	

Figure C-3. Virtual deviation survey for well NMSU-PG-1.